Local Knowledge of Coffee Productivity and Ecosystem Services in Coffee Plantations Surrounding Macizo Peñas Blancas Reserve, Jinotega-Matagalpa Departments, Nicaragua

A GUIDE TO USING THE CAFNET-NICARAGUA KNOWLEDGE BASE

Plate 1. Coffee farmer Guadalupe Rivera on his farm in La Chata community. Photograph taken by Carlos Cerdán, June 2008.

C. Cerdán[1-2]; G. Lamond[1]; T. Pagella[1]; G. Soto[2]; F.L. Sinclair[1]

[1] School of Environment and Natural Resources, Bangor University, Gwynedd, Wales, UK LL57 2UW
[2] Tropical Agricultural Research and Higher Education Centre (CATIE), Turrialba, Costa Rica.

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This guide uses an approach that was pioneered in Ghana (Moss *et al*, 2001) to introduce first time users of AKT5 to existing knowledge bases and it was subsequently used in Thailand (Pagella *et al*, 2002) and Lesotho (Waliszewski *et al*, 2003). The template for this document was used by kind permission of the authors of these previous documents. The software itself has been developed over many years primarily by Knowledge Engineer James Doores in collaboration with Edinburgh University in Scotland (UK).

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1. Local knowledge of coffee productivity and ecosystem services in coffee plantations surrounding Macizo Peñas Blancas Reserve, Nicaragua

A GUIDE TO USING THE CAFNET-NICARAGUA KNOWLEDGE BASE

1.1 What is the purpose of this guide?

This publication is intended to guide first time users through a knowledge base (Kb) created in **Macizo Peñas Blancas Reserve** of **Matagalpa and Jinotega Department, Nicaragua**. It has been designed to assist new users in exploring the local knowledge base that has been developed for the CAFNET project. The knowledge base contains agro-ecological knowledge primarily about interactions between coffee productivity and shade tree species used on plantations, and the role of coffee plantations in providing ecosystem services.

Greater explanation regarding the AKT5 methodology and the steps to creating a knowledge base can be found in the comprehensive user manual written by Dixon *et al* (2001) (a translation in Spanish is also available). The principles of knowledge base creation have been explained by Sinclair and Walker (1998) and Walker and Sinclair (1998); how this approach applies within a natural resource management context is discussed by Sinclair and Walker (1999) and Sinclair and Joshi (2000). The software and manual can be downloaded from the AKT5 website at **http://akt.bangor.ac.uk.**

1.2 Consulting knowledge bases (Kbs)

Local knowledge can help researchers and development workers explain the rationale behind farmers' actions and can contribute towards more effective decision making in developing appropriate strategies for particular development issues. Knowledge bases can be consulted by:

- viewing sets of *statements* that fall under specific *topics*,
- using search facilities within AKT to find out the details of particular *terms* (words),
- generating *diagrams* from *statements* and using these to investigate causal relationships, and
- using customised *tools* (small computer programs that are incorporated into AKT5 that interrogate and reason with the knowledge base)

1.3 The Agro-ecological Knowledge Toolkit (AKT5)

1.3.1 What is AKT5?

AKT5 is a methodology and software that enables the user to create a *knowledge base* about a chosen *domain* which is shaped by the topic of the knowledge base, the research area and the people chosen to be interviewed. In this case **coffee growers** were interviewed in order to collect '**local knowledge of coffee productivity and ecosystem services in coffee plantations**' surrounding **Macizo Peñas Blancas Reserve**. A knowledge base is built up by collating knowledge about a chosen topic from a variety of sources (usually farmers, scientists, extension workers and/or scientific literature).

So far, AKT5 has been used primarily as an analytical research tool to explore the extent and nature of agro-ecological knowledge at a wide range of localities. This has led to

profound changes in the way that research and extension are planned in areas of Africa (Kenya, Tanzania, Ghana and Cameroon), Asia (Nepal, Thailand, Sri Lanka and Indonesia) and Latin America (Colombia, Costa Rica and Nicaragua), as well as forming the basis for successful participatory crop improvement and the development of decision support tools for the production of extension materials tailored to farmer circumstances. When local knowledge is explicitly stored within a knowledge base, it can then be consulted by natural resource scientists, policy makers and development workers in a variety of ways to help them meet their own objectives.

1.3.2 What is knowledge?

To define *knowledge* is to enter a philosophical minefield; nevertheless an explicit definition is required in this context. For the purposes of AKT5, *knowledge* is the outcome of the interpretation of data, whereas, *data* is recorded observations that may be either qualitative or quantitative. *Knowledge* in this context could be called *interpreted observations* that are often shared within and across farming communities. *Knowledge* is distinct from *understanding*, which is a result of the interpretation of knowledge or data and is specific to the interpreter. These definitions are more fully discussed in Sinclair and Walker (1999).

1.3.3 What is a knowledge base?

A *knowledge base* is a store of knowledge that consists of a collection of *statements* and locally defined taxonomic relationships, created using AKT5 software. Each *statement* is tagged (referenced) with its source of knowledge (this could be a singular person, a number of people if it came from a group interview or a literature reference).

The knowledge is organised according to a number of principles:

- *topics* arrange knowledge around specific subject areas, e.g. '**soil erosion**'. *Topic hierarchies* gather similar topics under an umbrella title e.g. '**soil erosion**'**,** '**soil fertility**' and '**soil moisture**' all fall under the broader topic of '**general soil interactions**' (Figure 1), and

- *object hierarchies* organise knowledge about specific *objects* under umbrella terms, e.g. '**black guaba**', '**guarumo**' and '**helequeme**' are all types of trees found within coffee plantations and would therefore fall under the umbrella term '**fresh trees**', as they share attributes that make them suitable as shade trees (Figure 2).

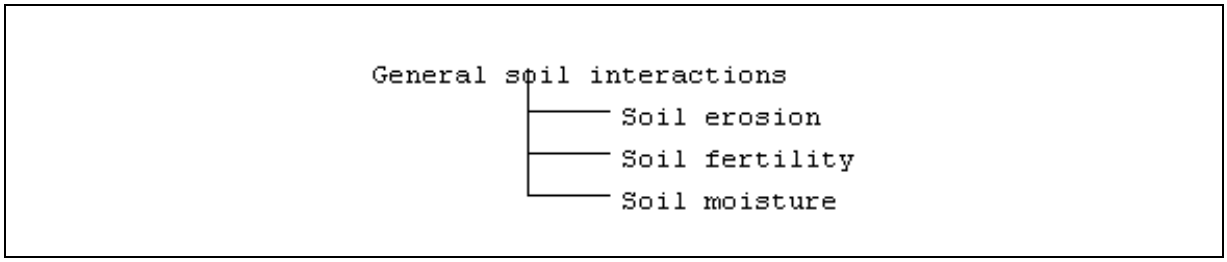

Figure 1. The topic 'general soil interactions' is arranged in a topic hierarchy tree with a list of subtopics.

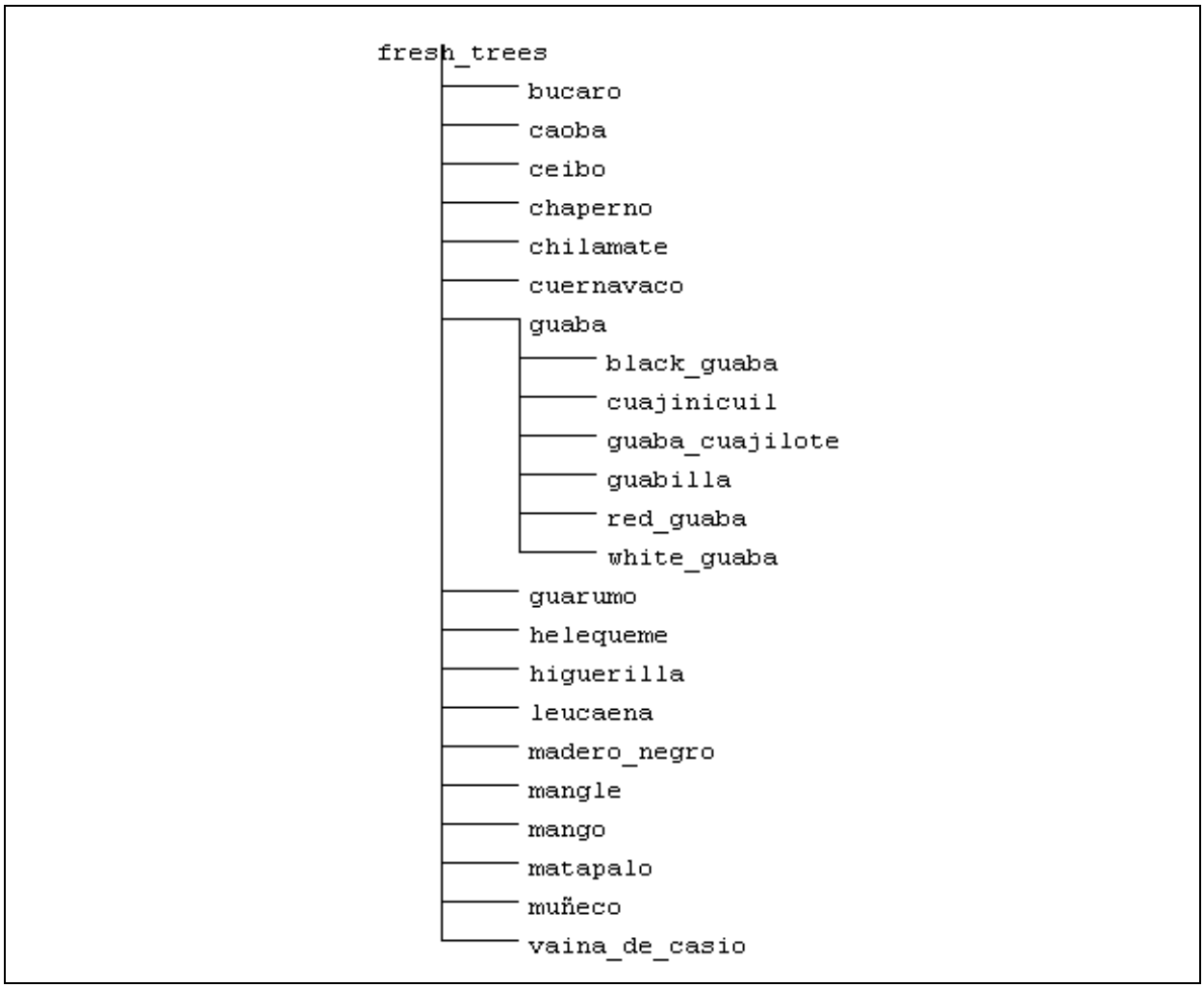

Figure 2. The object 'fresh trees' is arranged in an object hierarchy tree with a list of its subobjects.

2. The CAFNET - Nicaragua knowledge base: Context of the study

2.1 CAFNET

CAFNET is a four-year European Commission funded project that hopes to make some positive changes to how the coffee process chain operates in order to improve coffee farmer income while at the same time protecting 'biodiversity hotspots'. A major concern of the project is environmental services and how coffee farming practices can benefit the environment as well as the farmer. Approximately 125 million people across Asia, Africa and Latin America depend on coffee for their livelihoods and it is the second most valuable export commodity after petroleum (Lashermes and Anthony, 2007; Osorio, 2002). The importance of coffee both as a cash crop and as a possible 'buffer' crop around protected areas has been highlighted by the CAFNET project and the local knowledge research that has so far been carried out aims to lead to a better understanding of farming practices carried out by the coffee farmers, who are an integral part of the system.

Biodiversity is an important indicator of sustainable land use practices and, whereas most of the research on biodiversity in coffee agroforestry systems has concentrated on documenting tree species richness and abundance by surveys and data collection (Méndez et al, 2006), the objective of this work was to document the knowledge held by those involved directly with coffee production. This is in order to understand locally held perceptions of tree diversity and agro-ecological interactions within coffee agroforestry systems. For the local knowledge component of the CAFNET project the main objectives are:

1. to document local agro-ecological knowledge of coffee farmers on the diversity of species found within coffee plantations and the interactions between species in terms of productivity and sustainability, and

2. to identify any key gaps in the knowledge held by coffee farmers or scientists and to pull out any contrasting or comparative knowledge between coffee farmers and scientists.

2.2 Study area

Central America is the central geographic region of America, which connects northern South America (Colombia) with southern North America (Chiapas, Tabasco, Campeche and Quintana Roo Mexican states). Central America is made up of seven countries: Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama.

Central America has approximately 522,000 square kilometres, with coffee being grown on an estimated 893,000 hectares of this area (CEPAL, 2002). Coffee has been one of the main agricultural crops and source of export earnings over the last century, currently playing an important role in the national income of several countries; including 7.2% of the Gross Domestic Product (GDP) in Nicaragua, 4.2% in Guatemala and 1.3% in Costa Rica (ICAFE 2005).

Three areas were selected in Central America to take part in the CAFNET project and they were located in Guatemala, Nicaragua and Costa Rica. Selection criteria for the research areas were according to their geo-hydrological attributes, the percentage of land covered by

coffee plantations and their proximity to protected areas and wildlife parks; this was to assess their potential as buffer zones for purposes of enhancing biodiversity conservation and watershed protection in fragmented landscapes. CAFNET researchers have been working in El Hato Watershed, San Agustín Acasaguastlán Municipality, El Progreso Department, Guatemala; Macizo Peñas Blancas Reserve in Matagalpa and Jinotega Departments in Nicaragua; and Volcánica Central Tamalanca Biological Corridor in Cartago Province in Costa Rica.

Macizo Peñas Blancas Reserve is a protected area that is situated within the buffer zone around the Bosawas Biosphere Reserve, the latter being the largest forest reserve in Central America and the third largest in the world. The Macizo Peñas Blancas Reserve is politically part of three Municipalities of two northern Nicaraguan departments: El Cuá in Jinotega, and La Dalia and Rancho Grande in Matagalpa (Figure 3) (MARENA, 2003). The protected area consists of 11,300 hectares, located at 13º13´27″ N and 85º35´25 W, with the highest point in the reserve at 1745 meters above sea level. Coffee farms were situated around the reserve and, therefore, could be classed as a potential form of environmental protection and extension of the forest areas depending on the farming practices carried out.

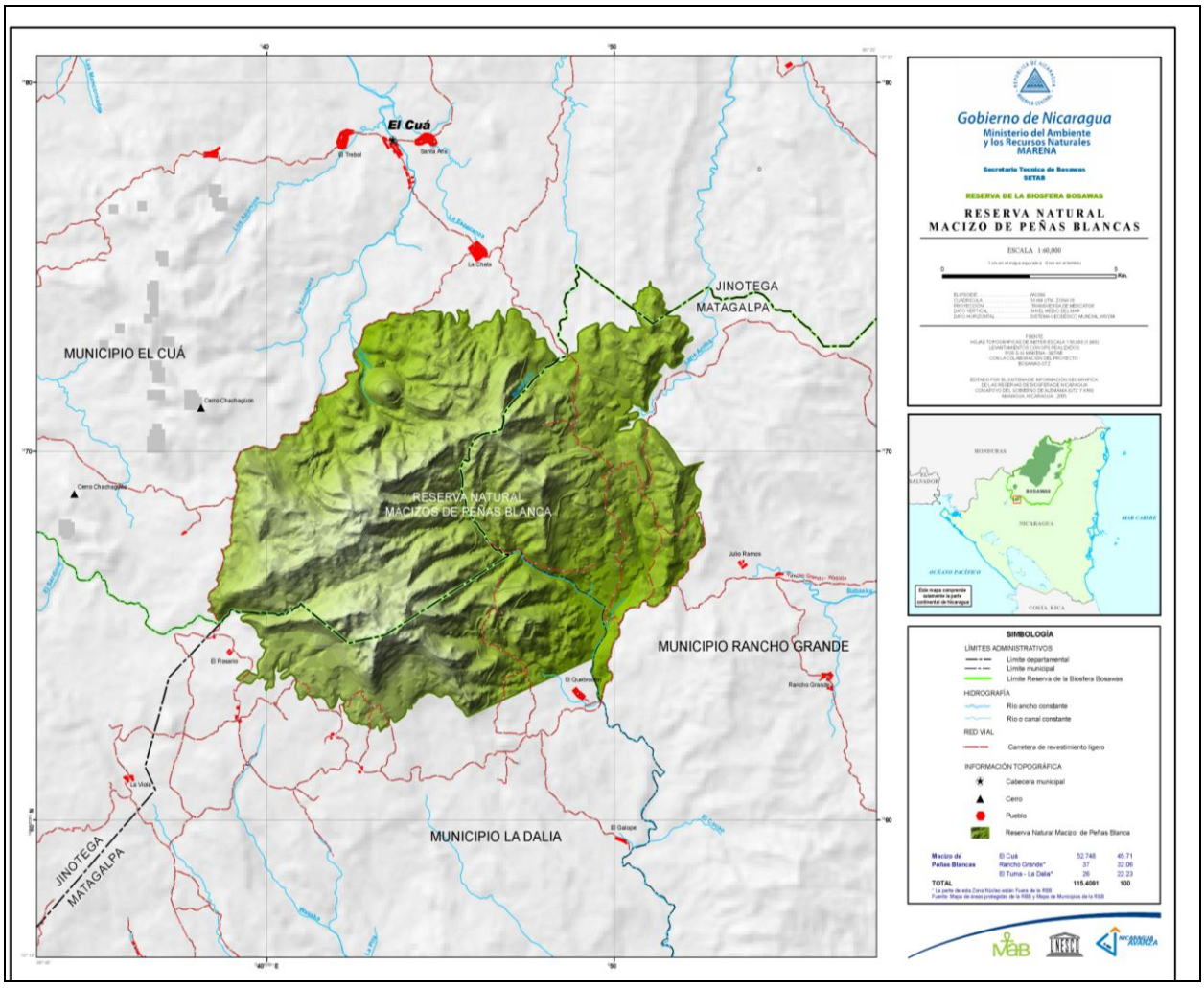

Figure 3. Location of Macizo Peñas Blancas Reserve.

2.2.1 Technical assistance for coffee farmers in study area

In comparison to the other CAFNET research areas in Guatemala and Costa Rica, the research areas of Matagalpa and Jinotega Departments in Nicaragua had much more training available for coffee farmers. In El Cuá Municipality, there was a Swedish coffee project that was running for 10 years (FondeAgro) and had started in the year 2000; it was aiming to increase farm income in two areas in Nicaragua (within Matagalpa and Jinotega Departments) by increasing both livestock and crop productivity through farmer capacity building. Project components included technical assistance for coffee and livestock production, and home garden management for female groups. There were more than 18000 persons such training from FondeAgro, including the majority of coffee farmers in El Cuá Municipality. Technical assistance throughout the different phases of coffee production was taking place. For instance, when interviews were being conducted, FondeAgro was carrying out a campaign promoting coffee pruning.

Another way that coffee farmers within the area were receiving training was through cooperatives (mainly consisting of small farmers). Coffee cooperatives were a common form of organisation by coffee growers in Nicaragua and through group organisation, coffee farmers would receive technical assistance from FondeAgro (in El Cuá) or from Nitlapan, Cecocafe and Cafenica (in Rancho Grande and La Dalia Municipalities). Nitlapan was a research institute of a private university, whereas Cecocafe and Cafenica were unions of cooperatives. For some farmers, in particular the larger farms, it was common to receive assistance from coffee buyers, as well as from the mentioned organisations. However, despite the various means of training and assistance being carried out, most were not systematically established.

The main technical assistance was provided by FondeAgro, through a company called Serviteca, but it had only been available over the last 3-4 years and had not yet reached all coffee farmers because it was focusing on only one municipality in the area (El Cuá). Technical assistance and training was often being accomplished through loans of money credits, and could cover further aspects such as farmer organisation, coffee certification, legal procedures, and help with trade. In the last two years, a competition on coffee quality has been held in order to show farmers the importance of the entire coffee production process in influencing the quality of cup. However, FondeAgro project is near to finishing and there is a risk that all the things obtained up until now will not continue without the institutional support.

2.3 Methodology

2.3.1 Location and definition of knowledge base

This guide is primarily focused on examining coffee farmers' explanatory knowledge of interactions between coffee productivity and the ecosystem of which the crop is a part. Coffee farming practices, the impact of such practices on ecosystem services, and knowledge about tree species diversity within the coffee farming landscape, was the basis for this research.

Interviews were conducted across eight communities surrounding Macizo Peñas Blancas Reserve. There was a variety of farm sizes with both conventional and organic methods being practised, to varying degrees. Coffee was growing at different altitudes within the

research area, with some farms being located in higher areas and consisting of few, if any, shade trees within the coffee plantations. These higher up full sun plantations were owned by large farmers and were not representative of the area (it was actually just two farms 'Las Brisas' and 'El Cielo'). There were other plantations, especially in Rancho Grande, which had more indigenous shade tree species intercropped with coffee; these trees had made up the forest land before the coffee plantations were established. The majority of farmers were managing their coffee under the shade of dominant species of *Inga*, but it was also the case that a range of different tree species could often be found within the farms.

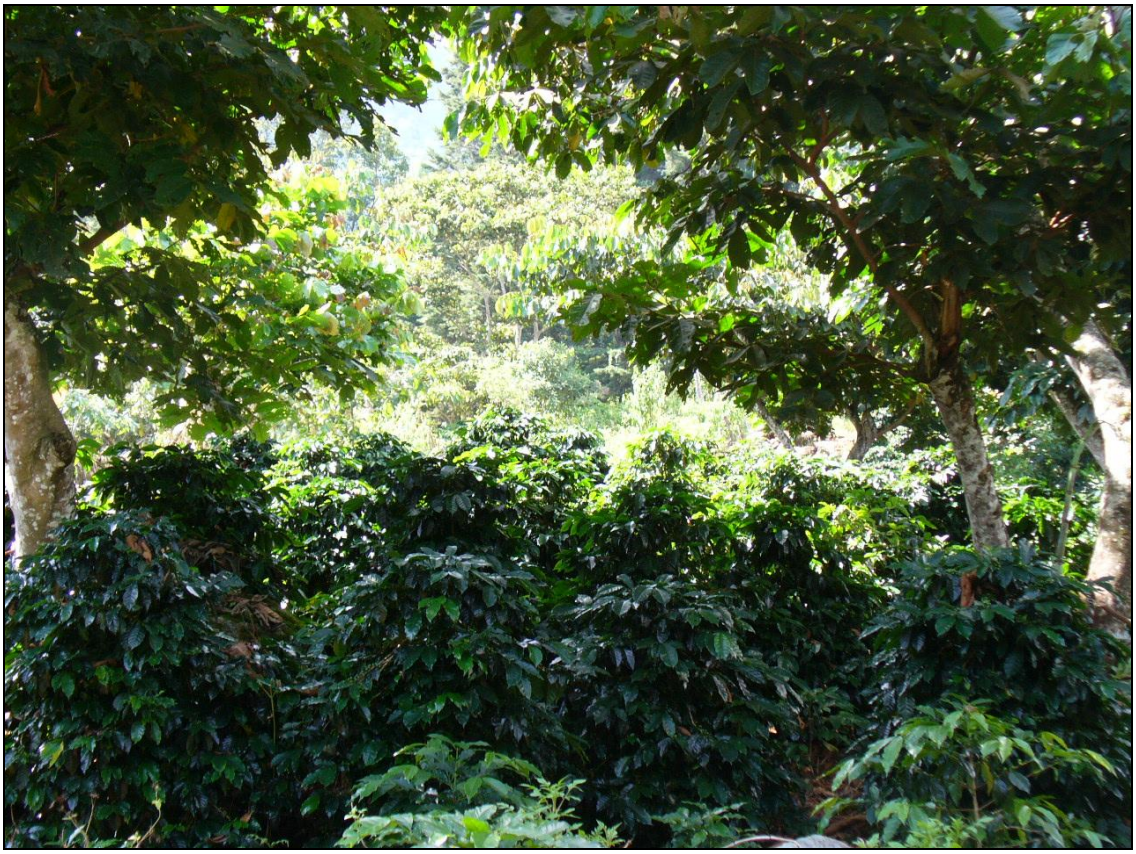

Plate 2. Coffee under *Inga* trees in Macizo Peñas Blancas Reserve. Photograph taken by Carlos Cerdán, May 2008.

2.3.2 Informant selection

Due to the fact that the majority of farms were known by local partners, informants were suggested by local technicians who were in charge of giving technical assistance to farmers (Serviteca and ADAC). Differences in levels of productivity and ecosystem services provision by farms was the initial stratification exercise, following advice given by the technicians who had identified varying methods of coffee plantation management. This strategy proved to be not consistent enough to provide useful comparisons, but there was noticeable difference between farmers whose training had varied and/or had different sized farms; age was also a factor that shaped the depth of knowledge that farmers had about species and the surrounding environment.

The farms included in the study were classified as small (less than 1 manzana[2] to 5 manzanas), medium (between 5 and 10 manzanas), and large (above 10 manzanas). Distinction could be made between different sized coffee farms due to differences in the composition and diversity of tree species planted with coffee; small producers were likely to retain more shade trees within coffee plantations to supplement their income and for subsistence purposes.

Farms were further stratified according to their position across a continuum of organic and conventional methods of farming; there were 'certified organic', 'uncertified organic', 'low conventional', 'medium conventional' and 'high conventional'. Some farmers had previously been certified organic but the cost of this was deemed too expensive for them to continue being certified, and they would apply small amounts of inorganic herbicides – making them 'low conventional', distinct from the farms classified as 'medium' or 'high' conventional.

2.3.3 Compilation of the knowledge base

Interviews with key informants were held on coffee plantations where possible and lasted no more than an hour, unless the informant was keen to continue. The interviews were informal and semi-structured, using non-leading questions in order to elicit informants' knowledge, rather than influence answers.

Notes were taken and digital recording devices were used where permission was granted; this then enabled the researchers to go through the interviews thoroughly afterwards and break them down into unitary statements to enter into the AKT5 knowledge base. This led to a process of iterative evaluation throughout knowledge base creation, with repeat interviews taking place where necessary to clarify or add value to what had already been said by informants.

Creating a knowledge base enables the local context of the knowledge to be attached to the sources and the statements that are entered from interviews with those sources; this is done by a 'memo' function. Source details that are required in AKT5 are the name of the informant, location of the interview, and gender. In the Nicaraguan case, other information included size of coffee farm, age, and farming method. Further context was recorded in source and statement memos.

2.4 The knowledge base

The cafnet_nicaragua Kb was built up from interviews with one female and nineteen male informants. The age of informants was categorised into 'below 35' (young), '35-60' (middle) and 'above 60' (old); the dominant age range was '35-60' with thirteen interviews, followed by 'below 35' with four interviews and 'above 60' with three interviews. Tables 1 and 2 (below) summarise the information gathered from different locations and different sized farms. As can be noted, interviews took place across a range of coffee farm sizes and communities.

There are a total of 720 statements in the Kb with 502 of these demonstrating causal relationships. A high number of causal statements would indicate a fairly high level of

[2] 1 manzana is equal to 0.69 hectares.

explanatory knowledge that was able to be articulated by the coffee farmers. Out of the 720 statements there are 92 conditions attached to statements; this means that there are particular conditions that need to be in place for the statement to be applicable and these should be considered carefully when analysing the knowledge base.

Table 1. Location of the sources from cafnet_nicaragua Kb.

Location	**No. of informants**	**No. of associated statements**
Colonía Agrícola	1	26
Divisiones del Cuá	2	44
El Cuá	1	143
Empalme Peñas Blancas	1	50
La Chata	5	331
Los Andes	3	78
Peñas Blancas	5	244
Santa Rosa	2	71

Table 2. Size of coffee farms and associated statements from cafnet_nicaragua Kb.

Size of coffee farm (cafetal)	**No. of informants**	**No. of associated statements**
Between 0-5 manzanas (small)	8	319
Between 5-10 manzanas (medium)	7	374
More than 10 manzanas (large)	5	235

Within the Kb there are a number of object hierarchies and topic hierarchies that have been created to enable the user to search chunks of knowledge much quicker than would otherwise be possible. How to do this will be explored in the following section.

There are 19 object hierarchies that classify trees and animal species according to the agro-ecological interactions that farmers attributed to them (e.g., 'good soil trees'). The object hierarchies show the importance of particular attributes of trees for them to be maintained in a farming landscape, with possible short and long term trade-offs evident (for instance, there might be a tree that attracts many animal species but has a negative impact on coffee productivity).

There are 34 topics arranged into five topic hierarchies that organise the farmers' knowledge under useful headings that can be searched easily by the user. The five topic

hierarchies are entitled ‘Commonly held knowledge’ (broken down into sections according to farm size, age, and farming method), ‘Trees and biodiversity’ (interactions between trees, mammals and birds), ‘General soil interactions’ (aspects of erosion, fertility, moisture), and ‘Water infiltration’ (impacts of different tree species and coffee plants on water infiltration within farms).

Plate 3. View from above a large coffee farm in the top of Macizo Peñas Blancas Reserve. Photograph taken by Carlos Cerdán, June 2008.

3. How to consult the knowledge base

3.1 Using the guide:

It is suggested that the user start with '**A quick sightseeing tour around AKT5**' to familiarise themselves with the different functions of the AKT5 software. Once this is completed the user should then be able to consult the knowledge base according to particular topics of interest using any of the examples provided:

- **Farmers knowledge according to farm size or farming method**
- **Desirable attributes of trees within coffee plantations**
- **Impacts of coffee plantation composition on soil fertility and water provision**
- **Coffee productivity and its relationship with agroforestry practices**

The topics given above indicate the type of knowledge contained in the knowledge base and the ways in which to access it will be explored below. After completing '**A quick sightseeing tour around AKT5**' the user will be able to consult the knowledge base using topics, different search options and exploring diagrams. These skills will then be reinforced and developed by the section entitled '**Exploring the knowledge base; some highlights from local knowledge**' which introduces more contextual information and how to utilise AKT5 tools.

Once the user has completed these sections they should then be able to explore the knowledge base independently. There are tools designed to help the user pull out relevant information and some of the more useful ones are listed in '**Appendix 1: Tools for analysing the knowledge**'. Definitions of key terms and concepts used in the sightseeing tour and the AKT5 software are included in '**Appendix 2: Glossary**'.

The user should note that not all functions of the software are explained in this publication because the software is used for both creating and accessing knowledge bases. The '**User Manual**' (Dixon et al., 2001) provides a more comprehensive guide to the software and how to create your own knowledge base.

3.2 A quick sightseeing tour around AKT5

This quick tour around AKT5 with the **cafnet_nicaragua** knowledge base is designed to help familiarise you with the AKT5 software and the ways in which you can manipulate a knowledge base.

Getting Started:
1. Install the **AKT5** program onto your computer by clicking on the appropriate icon from the **Start** menu.
2. Always start AKT5 and then load a knowledge base, never start by clicking on Kb file to open.
3. Open the **cafnet_nicaragua.kb** by selecting '**KB'** from the tool bar at the top of the page, clicking on '**Open Kb**'**…**then selecting the **cafnet_nicaragua.kb** from its saved location and clicking on '**Open**'.

Welcome Dialog Box

Read the '**Welcome Memo**' dialog box to get an idea of what the knowledge base is about. Select '**Further Details**' to find out where, when and how the knowledge base was made. Click on '**Pictures/Diagrams**', read the text at the top and then view each picture by clicking on it. When you have finished with each picture/diagram, click on the **X** in the top right corner to close the dialog box. The diagram provides background information about the livelihoods of the farmers who participated in the research. Click on the **X** in the top right corner to return to the 'Welcome Memo' screen.

Switching the language of the knowledge base (English-Spanish, Spanish-English)

In some knowledge bases, including this one, it is possible to switch from English script to a largely Spanish script[3]. To access this function go to the '**Tool**' drop down menu on the main toolbar in the top left hand corner of the page. Select '**transpose_formal_terms_and_synonyms (Kb, Position)**' from the '**General**' drop down menu which can be found under '**System Tools**' (Figure 4).

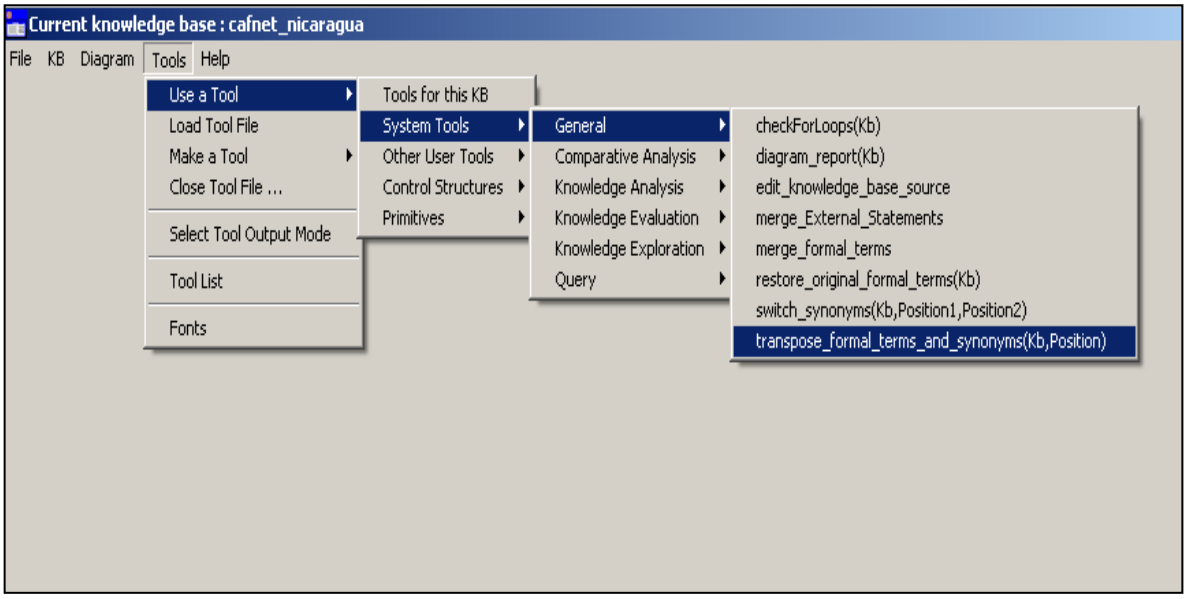

Figure 4. 'Tools' menu.

A new dialog box will appear, click on '**Run**' (select '**Description**' to see an explanation of the tool). Another dialog box is produced; the name of the knowledge base will appear in the '**KB**' field and the '**Position**' field will be blank. Type in '**1**' in the '**Position**' field (this will change the current formal terms to their first position synonyms). Once you have done this, select '**Continue**' and wait for the tool to run (for large knowledge bases this can take a few minutes). Where there is no synonym available in position 1, the term will keep its original name in the main Kb language.

[3] This is achieved by utilisation of the synonym function of the AKT5 program. This allows substitution of all the main language formal terms for a listed synonym. Switching formal term/synonym positions requires the use of an AKT5 system tool.

When the tool has finished running, a '**Tool output**' is produced which tells you it has successfully carried out transposing the terms. Click on **Close** to close the window, and then click on **X** to close the list of tools and return to the main AKT5 screen. *(To return to the original format i.e. the English script, you would need to use the tool '**restore_original_terms(Kb)**' which is found in the same list of tools as '**transpose_formal_terms_and_synonyms (Kb, Position)**').*

When viewing the statements and diagrams after converting the knowledge base into Spanish script, you will see that some words remain in English. These are reserved words that have restricted meaning within the AKT5 system. Topics, topic hierarchies and sources cannot be switched using this tool and will remain in the main Kb language. It is only formal terms and statements which can be viewed in the Spanish translation. Computers with modern versions of the Windows operating system will also be able to show the diagrams in Spanish

Now, let's look at Topics by selecting '**Topics**' from the '**KB**' drop down menu on the toolbar on the main AKT5 screen *or* from the '**Welcome Memo**' dialog box.

Topic hierarchies

Topics are ways of organising information around a particular subject e.g. 'Soil erosion' or 'Flowering of tree and plant species'. In ***Topic hierarchies*** specific knowledge can be grouped together as topics and arranged under more general headings, e.g. 'Soil erosion', 'Soil moisture' and 'Soil fertility' all fall under the general topic hierarchy of 'General soil interactions'.

On the left you can see a list of the topic hierarchies in the knowledge base. Highlight **'Commonly held knowledge**'. On the right you will see a dialog box with a column called '**Topics in hierarchy**' containing a list of all the topics in this topic hierarchy. Next to this column you will see '**Commonly held knowledge**' highlighted in the '**Topic**' box and immediately below all the '**Immed. Subtopics**'.

Select '**View Tree**' and scroll down the page; this will show you the full topic hierarchy with *all* its 'subtopics'. Click on **Close** to go back to the previous window.

Now select '**Common knowledge of small farmers**' from the '**Topics in hierarchy**' list. You will see that it now appears in the 'Topic' box with '**Commonly held knowledge**' specified as the 'Supertopic' above it and '**Small middle farmers**' specified as one of the 'Immed. Subtopics' below it.

Close this dialog box to return to the '**Topic Hierarchies**' box. Now highlight in turn each topic hierarchy listed under 'Topic Hierarchies'. Answer the following question:

Question: What topics are shown to be in the topic hierarchy 'Water infiltration'?

Click on **Close** on both dialog boxes to return to the 'Welcome Memo' and **Close** again to arrive at the main AKT5 screen.

Sources

Sources tell you the origin of a statement. All statements have a source, which can be of 2 types: an interview with a person (e.g. a farmer) or a literature reference (e.g. a journal article). In the case of the Nicaraguan knowledge base, all the sources are coffee farmers surrounding Macizo Peñas Blancas Reserve.

Go to the tool bar on the main AKT5 screen (top left) and select '**Sources**' from the '**KB**' drop down menu.

On the left is a list of all the sources interviewed for the knowledge base. Let us look at one of them. Highlight the name '**Arturo Cruz Marín Peñas Blancas 2008a**' and click on '**Details'**. A dialog box appears giving you the name of the person interviewed, the interviewer and date of interview. You are also given the gender, age category, farm size category, farming method, and a location which is their community of residence. If you select '**Memo**', you will be given any further details that the creator of the knowledge base deemed important contextual information (in this case there is not a memo).

Click on **X** on all three dialog boxes to return to the main AKT5 screen.

Topics

From the tool bar on the main AKT5 screen select '**Topics**' from the '**KB**' drop down menu.

This gives you a list of all the topics in the knowledge base. Highlight '**Trees and mammals**' and select '**Details/Edit**'. In the dialog box that appears you will see in the 'Boolean Search String' how the topic was created – it is a search for any of the following object terms – 'todos_los_árboles' (all_trees) and 'mamiferos' (mammals).

Click on '**Show use in statements'** at the bottom of the dialog box and a list of all the statements on 'Trees and mammals' will appear. There are 23 statements in all. As you scroll through the list of statements you will notice that the translation does not sound like a natural use of English (or synonym language if you are using the transpose_formal_terms_and_synonyms tool) - this is illustrated and explained further on. **Close** the list of statements and the 'topic details' dialog box.

Try the same thing with the topic '**Soil fertility**'. Answer the following question:

Question: How many statements are there on 'soil fertility'?

You can see that the number of statements generated by a topic is often a large number to look through. We will now continue to look at smaller collections of knowledge.

Close all open dialog boxes and return to the main AKT5 screen.

All knowledge in the knowledge base is represented by ***statements*** – we call these the ***basic units*** of the knowledge base. There are 4 different types of statement. ***Attribute statements*** tell you about the properties (attributes) of something – they are descriptive.

Causal statements give you information about cause and effect relationships. ***Comparison statements*** compare the properties of two objects. ***Link statements*** represent any connections between objects that cannot be represented using the other statement types.

Please be aware that AKT5 automatically generates a natural language translation in stylised English and that the same process will apply for conversion into the other languages that are represented as synonyms. This will be explained in the relevant sections below.

Object hierarchies

What we refer to as ***objects*** are words used to refer to material or conceptual things e.g. pests, soil, trees, birds, policy. ***Object hierarchies*** are another way of organising knowledge by arranging specific objects under more general headings (these also have to be object terms) e.g. *cuernavaco, madero negro* and *guarumo* are all types of tree classified as 'arboles_frescos' (fresh trees) by farmers. Therefore, *cuernavaco, madero negro* and *guarumo* are all subobjects of the object 'arboles_frescos'. 'Arboles_frescos' is, then, a superobject of the objects *cuernavaco, madero negro* and *guarumo*. Object hierarchies are similar in structure to topic hierarchies.

From the tool bar on the main AKT5 screen select '**Object Hierarchies**' from the '**KB**' drop down menu.

On the left you will see a list of the object hierarchies in the knowledge base. From this list, select '**arboles_de_sombra**' (shade trees). On the right a dialog box will appear and you will see a long column containing a list of all the '**Objects in Hierarchy**'. To the right of this you will see '**arboles_de_sombra**' highlighted as the '**Object**' and immediately below are the '**Immediate SubObjects**'.

Click on '**View Tree**' and scroll down the page. This shows you the full object hierarchy with *all* its 'subobjects'. Click on **Close** to go back to the previous window.

Now select '**arboles_buenos_para_sombrear_cafe**' (good shade trees) from the '**Objects in Hierarchy**' list. You will see that this term appears in the '**Object**' box with '**arboles_de_sombra**' specified as the '**SuperObject**' above it and *bucaro, cuernavaco* and *muñeco* specified as the '**SubObjects**' below it.

Close all dialog boxes.

Formal Terms

Formal terms are the key components of statements. They are essentially singular words or words strung together. ***Objects*** (as described above) are one type of formal term. Other types of formal term include ***actions*** – activities with a human agent, e.g. harvesting or planting, and ***processes*** – activities without a human agent, e.g. growing or infiltration. You will notice that underscores e.g. dry_season, are used to connect two words to make a single formal term in AKT5. Terms which require a capital letter are put in inverted commas e.g. 'Inga spp.'.

Go to the toolbar on the main AKT5 screen and select '**Formal Terms**' from the '**KB**' drop down menu**.**

Click on the downwards arrow to scroll down the '**Type**' menu to see the different types of formal terms within the Kb. Select '**object**'. All the objects in the knowledge base are now listed. Scroll down and get an idea of the objects in the knowledge base. Highlight 'guaba' and select '**Details**'. This tells you what 'guaba' is – the most common shade tree found on coffee plantations in the research communities (Figure 5).

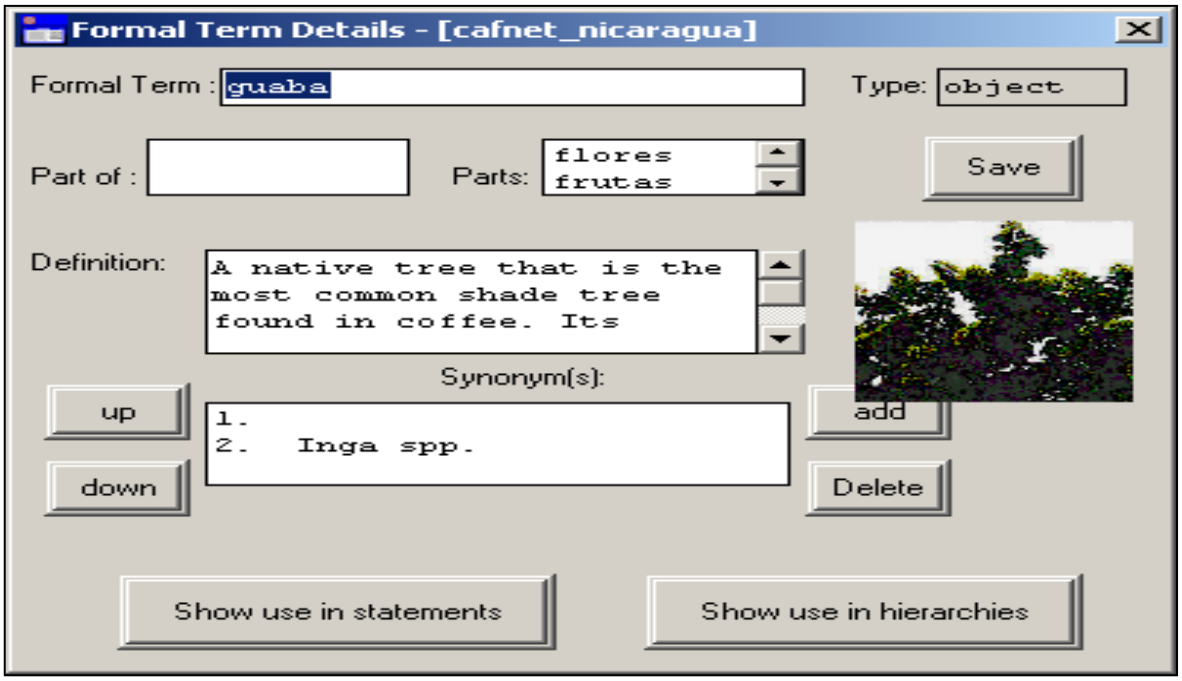

Figure 5. The 'Formal Term Details' box provides a brief description including information on the type of formal term, definition, synonym and a thumbnail photograph (if one is available). You can click on the thumbnail to enlarge the picture to see it more clearly.

Understanding the 'Formal Term Details' box (Figure 5)
Part of: This dialog box shows if the formal term is a part of something else (e.g. flowers are a part of trees)
Parts: This shows if a formal term has parts that are represented in statements. In the example given above there are statements about the part 'fruits' of guaba.
Definition: Provides further information about the formal term.
Synonyms: Lists the synonyms attached to a specific formal term. During knowledge base development in Nicaragua, the standard practice has been to include the first synonym as the Spanish translation. The second synonym is the scientific name. Where possible all plants and animals have scientific names entered as their synonyms because of the differences possible in local terminology. In the case of no English equivalent, the Spanish term is used.

Now select '**Show use in hierarchies**'. You will see that 'guaba' appears in many object hierarchies (Figure 6). Select **OK**.

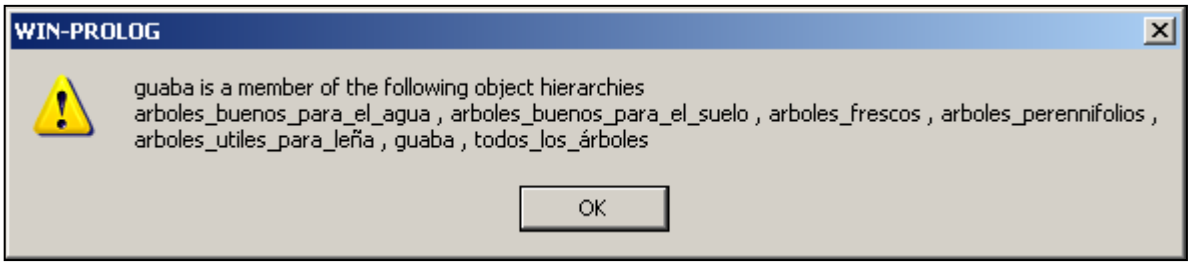
WIN-PROLOG
guaba is a member of the following object hierarchies
arboles_buenos_para_el_agua , arboles_buenos_para_el_suelo , arboles_frescos , arboles_perennifolios , arboles_utiles_para_leña , guaba , todos_los_árboles
OK

Figure 6. Object hierarchy details of formal term.

Click on '**Show use in statements**'. The 26 statements that appear are all the statements in the knowledge base that mention the term 'guaba'.

Introduction to Diagrams

Diagrams are a way of representing interacting statements. However, only ***causal*** and ***link*** statements can be represented diagrammatically. One statement is represented by two ***nodes*** (a rectangular or oval box) connected by an arrow. The different colours and shapes of the boxes indicate different types of node – action, process, object and attribute nodes. The words written within the nodes are key terms used within the statements. The arrows represent the linkages between nodes. It is possible to view diagrams in either English or another language (when using the '**transpose_formal_terms_and_synonyms (Kb, Position)**' tool) with the latest version of Windows 2000.

Repeat the process outlined above to show the '**Formal Term Details**' of the object '**banano**' (banana).

Then, select **'Show use in statements**' within the '**Formal Term Details**' box. Click on '**All Statements**', shown under the '**Diagram Selection Type'** at the bottom of the dialog box.

The diagram that is generated will show you all the statements containing '**banano**' that are able to be represented diagrammatically ('**causal**' and '**link**' statements).

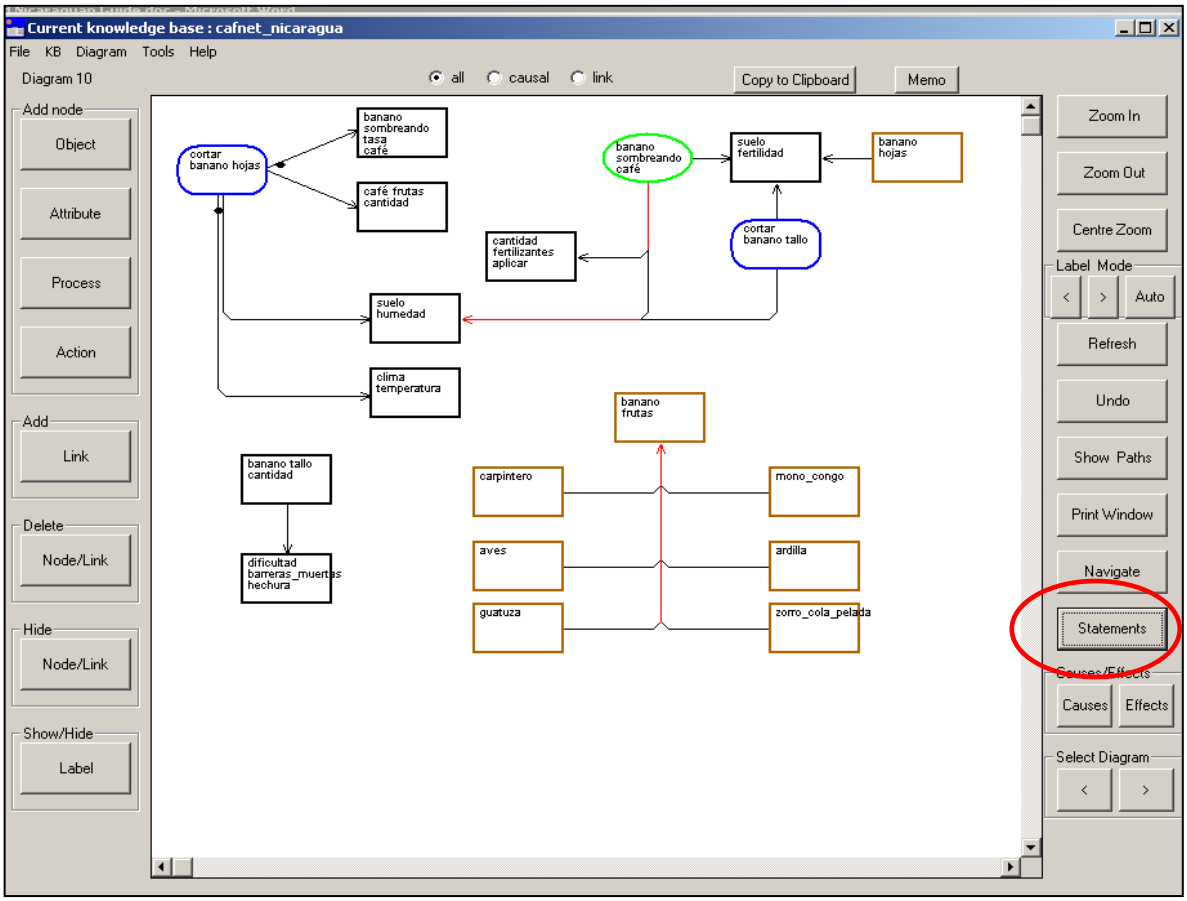

Figure 7. Banano diagram.

If you want to find out more about what is being said by a node, e.g. 'banano tallo cantidad', you can click on the '**Statements**' button (circled in Figure 7 on the right) to get a list of all the statements represented in the diagram. Then select the relevant statement (in this case no. 392) and click on '**Details**'. From doing this, you will see a dialog box that contains the natural language statement at the top and the formal language equivalent at the bottom (Figure 8).

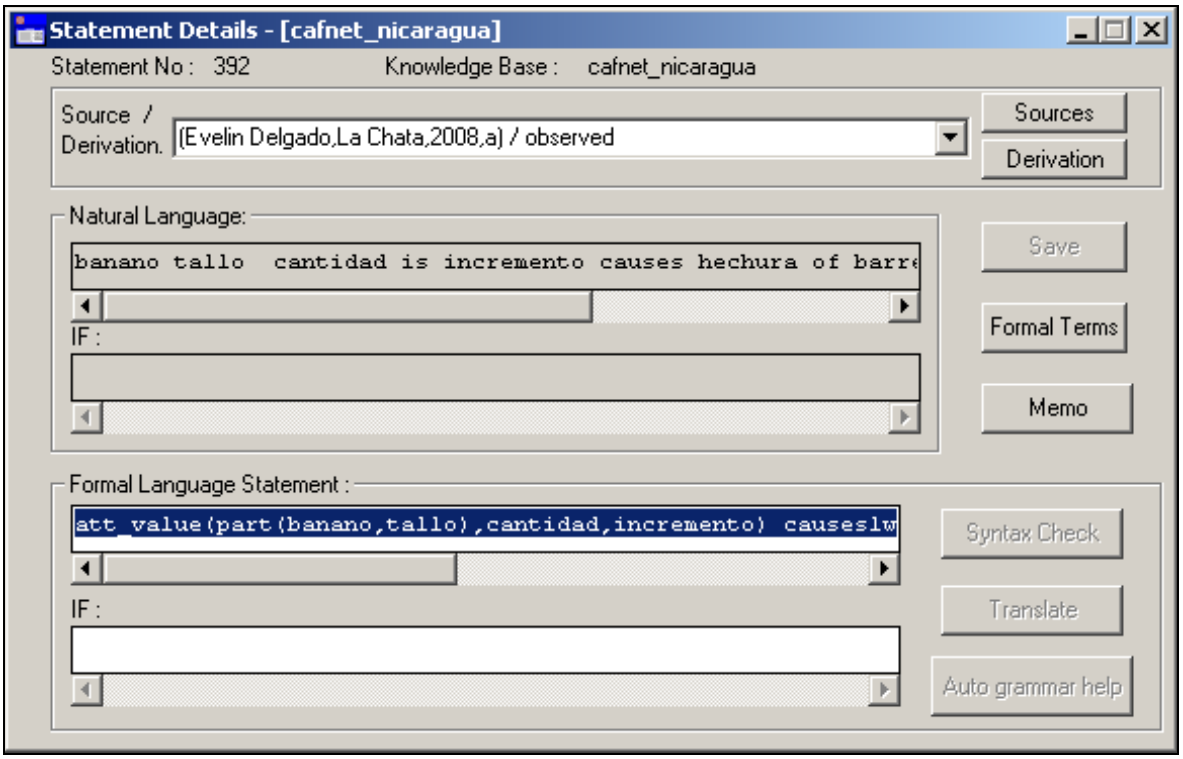

Figure 8. Statement details dialog box.

Now click on '**Formal terms**', select '**barreras_muertas**' and then click on '**Details**'; this will give you an explanation of the selected formal term. **Close** all the dialog boxes to return to the diagram.

Statements are typed into the knowledge base as ***formal language statements*** using a formal grammar (like a code) specific to AKT5. The AKT5 program translates the ***formal language statements*** into stylised natural language equivalents. Because of this computer generated translation, some statements in the knowledge base do not sound like natural English.

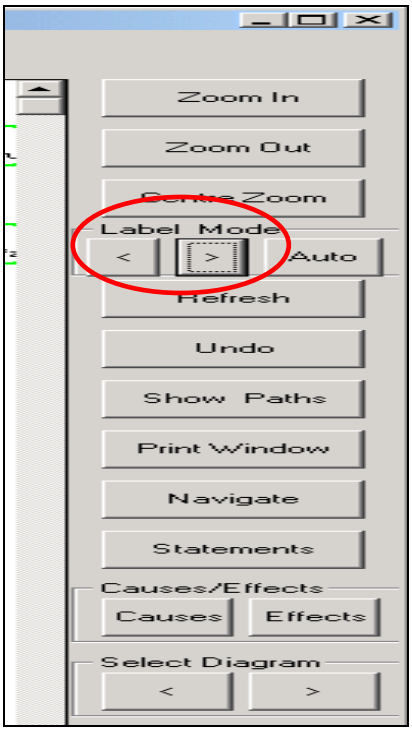

Figure 9. Diagram options.

Diagram options

Click once on the '**Label Mode**' button (circled in Figure 9). This will then show arrows that indicate causal relationships between nodes.

Click twice on the '**Label Mode**' button. This gives you the statements written on the diagram in full. You can make the statements more legible by using your mouse to drag the nodes across the screen to separate them out.

When working with complex diagrams it can be too confusing if all labels are pictured. Turn the label mode off by clicking a third time on '**Label mode**'.

By clicking on the '**Zoom Out**' button you will be able to see all the nodes that have been generated by the diagram. You can then click on '**Zoom In**' to restore the diagram to its original view.

Click first on '**Navigate**' and then a node (in this case, click on '**cantidad fertilizantes aplicar**'); this will generate the immediate causes and effects of that node. The selected node will be highlighted in green and additional nodes will appear connected to it. Carefully drag sideways all new nodes to reveal any further nodes underneath (by pressing the left-hand mouse button over the node and dragging the node away). Red lines indicate that there is more then one line or arrow on top of one another.

If you select '**Show KB Diagrams**' from the '**Diagram**' drop down menu on the main toolbar (top of the screen), you can look at diagrams that have been organised previously. Alternatively, diagrams can be browsed by clicking on the buttons underneath '**Select Diagram**'.

When you have finished, go to the main toolbar (top left-hand corner) and select '**Hide Diagrams**' from the '**Diagram**' drop down menu. This will return you to the main AKT5 screen.

Boolean Search

Go to the main toolbar (top left) and select '**Boolean Search**' from the '**KB**' drop down menu. You will see '**Display Kb terms of type**' in the top left-hand corner of the dialog box with '**formal terms and sources**' underneath it. Click on the downwards arrow next to '**formal terms and sources**', scroll down and select '**object**'.

Select '**café**' from the '**List of existing terms in Kb of the specified type'** and click on '**Details**' to see the definition and/or synonym of that formal term. Then **Close** the '**Formal Term Details**' dialog box by clicking on **X** and this will take you back to the '**Boolean search dialog box**'.

While the same term is highlighted, click on '**Select**' and '**café**' will appear in the '**Boolean Search String**' at the bottom of the dialog box. Then press the '**AND**' button under '**Boolean options**'. Now highlight '**erosión**' (a process) and click on '**Select**' once more. The search string will now have '**café and erosión**' as its search criteria (Figure 10).

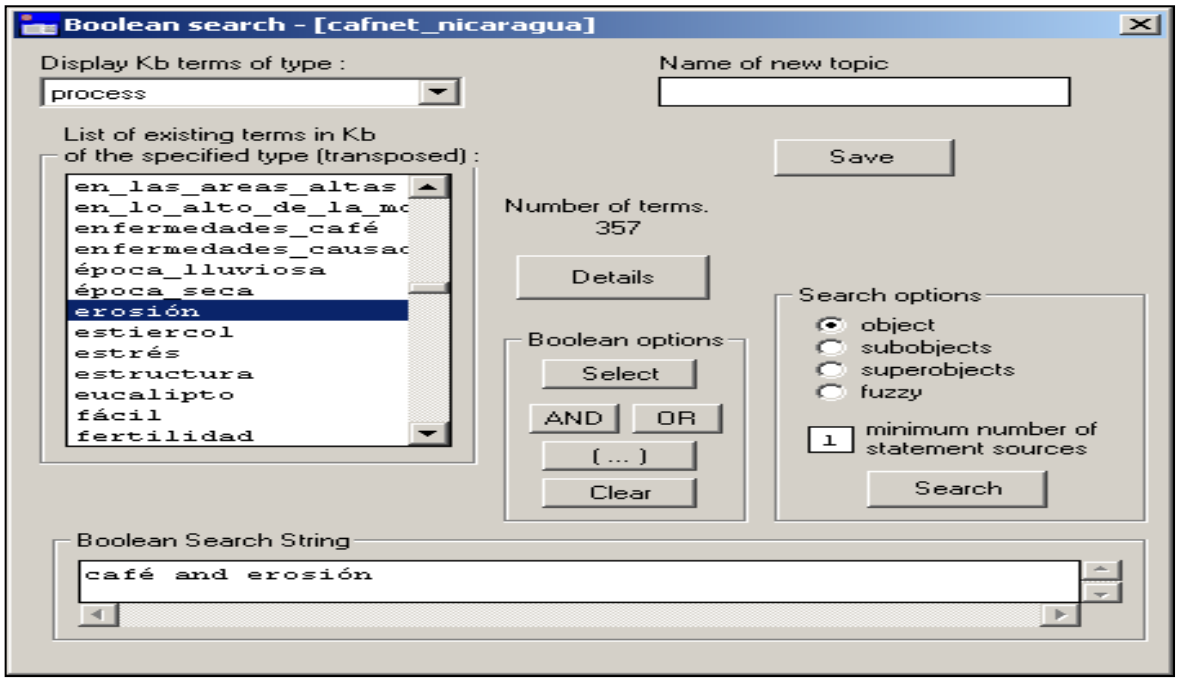

Figure 10. Boolean search dialog box.

When ready, click on '**Search**'. Three statements will appear. These are the only statements in the knowledge base which include both '**café**' *and* '**erosión**'.

Boolean search options

There are a variety of '**Search options**' you can choose from (Figure 11). You can select to include '**subobjects**', '**superobjects**' and '**fuzzy**' in the search. '**Fuzzy**' makes sure search terms that have prepositions in statements are included, e.g. '**in_high_altitude**'.

You can also filter statements according to the number of sources attached to the statements. For example, if you only want to pull up statements with at least three sources attached to them, you enter '3' into the box next to '**minimum number of statement sources**'.

Close the '**Search results'** dialog box by clicking on **X**. In the '**Boolean search**' dialog box select '**Clear**' under '**Boolean options**' to delete the search string.

Select the same terms again, '**café**' and '**erosión**', but this time select '**OR**' instead of '**AND**' from the '**Boolean options**'. Then, click on '**Search**'.

Now you will have 267 statements. This is because you have selected all the statements that include either '**café**' *or* '**erosión**'.

Close the '**Search results'** dialog box by clicking on **X**. In the '**Boolean search**' dialog box keep '**café or erosión**' in the '**Boolean Search String**' but this time select '**subobjects**' in addition to '**object**' under '**Search options**' (Figure 11). Click on '**Search**' once more.

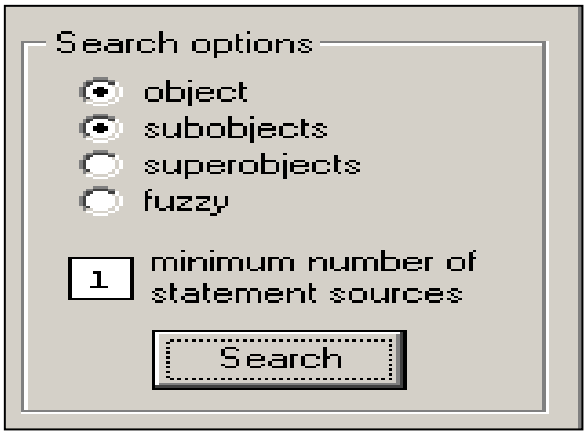

Figure 11. Search options dialog box.

You will now have 282 statements because, besides the statements that include the term 'café', you have also selected statements that relate to the subobjects of 'café'.

Close all the dialog boxes by clicking on **X**. This will return you to the main AKT5 screen.

Closing a Knowledge Base

Close the knowledge base by going to the main toolbar and selecting '**Close Kb**' from the '**KB**' drop down menu. **Close** AKT5 by selecting '**Exit from AKT5**' from the '**File**' drop down menu.

4. Exploring the knowledge base: some highlights from local knowledge

From practicing with '**A quick sightseeing tour'**, it should now be possible to explore the knowledge base more thoroughly. Some of the initial findings from the local knowledge research have been introduced below to help develop your skills in navigating around the knowledge base, as well as add a bit more context to the research findings. Tools that can aid your exploration of the knowledge are given, where relevant, at the end of each section (some of these are explained in Appendix 1).

Section 4.1 explores the origin of farmers' knowledge surrounding Macizo Peñas Blancas Reserve and how training and technical assistance impacted upon farmer understandings of agro-ecological processes.

Section 4.2 examines classification of trees in the research area according to specific attributes and how these relate to tree species' impacts on soil conservation and water protection.

Section 4.3 is a summary of farmers' knowledge about tree interactions with soil fertility, water sources and climatic regulation, and how this knowledge affects the tree composition of coffee plantations and the wider landscape.

4.1 Derivation of farmers' knowledge

The statements in the cafnet_nicaragua knowledge base were given derivations according to the origin of the information. This is useful to know during kb analysis, particularly in the case of inconsistencies between farmers, or even with the same farmer over several interviews. The main derivations used were 'observed' knowledge acquired from first hand experience, and 'hearsay' knowledge that had been heard from someone else but had not been observed first hand.

4.1.1 Knowledge derived from hearsay and first hand observation

Most of the information within the knowledge base came from observations made by farmers themselves but there was also knowledge that could not have been observed without the necessary equipment and expertise and, thus, was more likely to have come from technical advisors. Much of the terminology and knowledge articulated by coffee growers was said to originate from technical training and was not always clearly understood by the farmers interviewed. For instance, two farmers from La Chata Community and one farmer from Empalme Peñas Blancas Community stated that 'the applying of herbicides causes the death of soil microorganisms' (Kb Statement No. 568). When asked how they knew this happened the reply was they had been told at training events. Two of these farmers also said that they learnt that the death of soil microorganisms leads to negative consequences, such as 'a decrease in fertility of soil' (Kb Statement No. 569). Much of the knowledge within the Kb that mentions micro life and processes within farming came from trainings, clearly because such explanations could not be formulated by general observation with the naked eye.

An issue found with farmers' explanations originating from 'hearsay' was that they were not always clearly understood and seemed prone to distortion. For example, in a memo attached to Statement No. 568, a farmer said that glifosato (glyphosate) herbicide had lower

negative effects on soil microorganisms than other kinds of herbicide, but he could not substantiate the statement any further. The available knowledge that involves soil microorganisms was all learnt from various trainings, including the following statements:

- The burning of soil causes death of soil microorganisms (Kb Statement No. 290)
- Soil microorganisms increase the amount of soil organic matter (Kb Statement No. 291)

Another example of knowledge learnt through training and technical assistance was the biological process of nitrogen fixation. Farmers associated nitrogen fixation with attributes of *Inga* and *Erythrina* genus (two of the most common types of shade tree in the region). Farmers recognised trees with pod shape fruits as nitrogen fixer species; this was because of trainings that taught farmers how the shape of fruits can indicate further attributes of a tree. From being taught these skills of association, farmers were then able to observe for themselves the effects of particular tree species according to what they had learnt from trainings. A farmer from La Chata Community mentioned acacia (*Prosopis juliflora*) as a species able to fix nitrogen (Kb Statement 341) and said in the interview that he had learnt in the trainings about the pod shape of the fruits; this then resulted in him observing the effect on soil of the trees that he knew had such attributes. A farmer from Empalme Peñas Blancas Community also mentioned that a technician showed him 'the seeds that *Inga* trees have in the roots, and that are fixing nitrogen". He was using the word 'seeds' when referring to root nodules.

Plate 4. Farmer showing the 'seeds' on the roots of an *Inga* tree in Empalme Peñas Blancas Community. Photograph taken by Carlos Cerdán, May 2008.

Although knowledge about nitrogen fixation was recorded during interviews, it was not clearly understood by the farmers, with two farmers (one from Peñas Blancas Community and another from Divisiones del Cuá Community) explaining 'nitrogen fixation' in various ways during the interviews, seemingly distorted from what they had originally been taught in training sessions. The aforementioned farmer from Peñas Blancas Community was visited three times, and in each interview he varied the 'fixation' attribute of the *Inga*

genus; first of all he said that *Inga* species fix nitrogen, during the second interview he said that they fix calcium and in the last visit he said that they fix phosphorus. On the whole, farmers knew the word 'nitrogen' but were unable to explain it further (as illustrated by the eight statements in the Kb that are limited in their explanatory depth). This indicates that some aspects of the farmers' technical training were being repeated in whole or part, but the farmers were lacking a full understanding of the processes being talked about.

4.1.2 Contrasting knowledge

The knowledge that was derived from on-farm observations by farmers is detailed in its information about the physical attributes of different tree species that could be found in the farming landscape; the feeding habits of various mammals and birds; seasonal changes; and other directly observable features within coffee farms. This contrasts with the knowledge derived from training sessions and technical advice, which tends to revolve around the different chemical components needed to both increase soil fertility and the productivity of coffee plants. The technical and the first hand knowledge can be complementary when both are understood properly, but when trainings have not been understood (perhaps because of a lack of concrete examples that can be observed by farmers) farmers' explanations can prove to be inconsistent, even on an individual basis.

4.1.3 Summary

In the cafnet_nicaragua knowledge base, the knowledge gained from first hand observation and experimentation is different from that gained from trainings because technical advisors tended to talk about the further detail of agro-ecological processes that farmers could not easily observe first hand. Some of the teachings could be correlated with what was observed on farms, for example, the root nodules of *Inga* and the tree species' effect on the soil; but, other teachings were not so well understood because of the terminology used or because they were describing the 'unseen' processes of agro-ecological interaction.

Tools

Useful AKT5 tools:

- Boolean Search tool (found under KB/ Boolean Search). Can be used to search statements that are attached to different derivations (run the tool by selecting Display Kb terms of type/ derivations and then the derivation you want to see the statements of).

4.2 Local classification of trees and their attributes

Even though there was a common pattern to which shade tree species were dominant across coffee plantations, there was still a relatively high diversity of species that could be found within the farms surrounding Macizo Peñas Blancas Reserve. This was due to the utilisation of tree species for more purposes than just shade for coffee; they were being used for a range of functions, such as fences, fruits within the family diet, medicine, amongst many others. Moreover, because of the small distance to forest areas for farmers, either within the reserve or as a part of the farms, the knowledge of coffee growers about attributes and characteristics of many trees species was very high.

Trees were classified according to physical attributes; factors influencing how trees were observed to interact with their local environment. Many trees were utilised for a specific purpose by farmers (i.e. food, timber, firewood, shading coffee) but were also observed to

impact on the environment in various ways that were often secondary to the primary purpose.

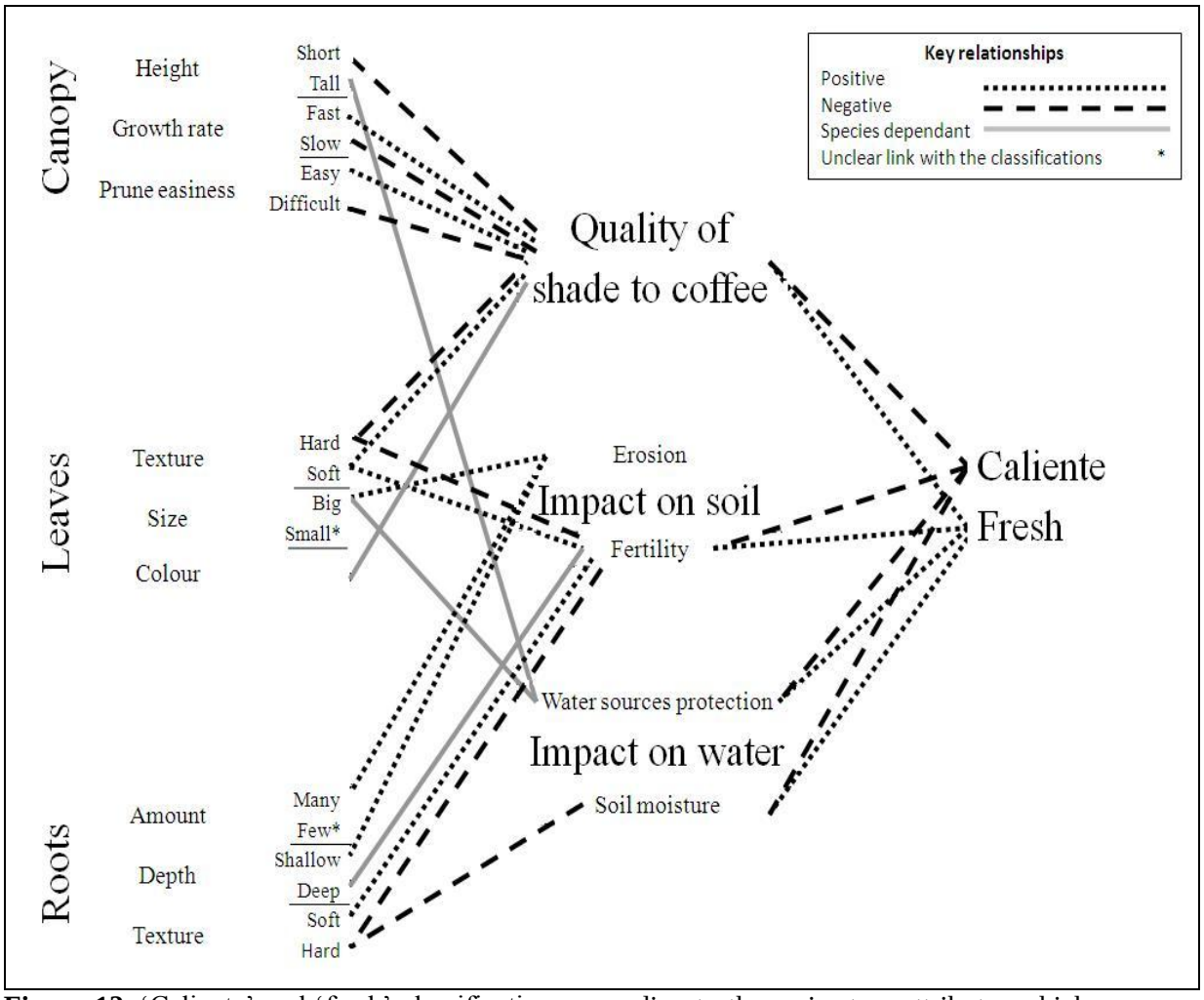

Figure 12. 'Caliente' and 'fresh' classifications according to the major tree attributes which were influencing shade quality, soil and water, as identified by farmers.
Notes: 'growth rate' indicates not only the speed at which a species was said to grow, but also the likelihood of survival after planting and/or the re-growth amount after pruning.

The diagram (Figure 12) illustrates the way farmers' classified trees and the way that tree attributes were feeding into some classifications but not others (e.g., leaf texture impacts on soil fertility and indicates whether a tree might be considered 'caliente' or 'fresh', whereas, leaf size impacts on soil erosion but does not feed into the 'caliente' or 'fresh' categories). Particular physical attributes were considered generally negative in their environmental impacts, while others were generally positive, but it depended on a combination of attributes that determined whether a tree was 'caliente' (negative) or 'fresh' (positive) overall. The values in Figure 12 with grey lines extending from them require further explanation:

Canopy height
Trees with a tall and broad canopy (e.g., chilamate of the *Ficus* genus) were associated with protecting water sources, while trees with a tall but narrow canopy were more frequently

classed as ‘caliente’ trees (or ‘áridos’ - translated as *hot* or *arid*). The trees with a narrow but tall canopy were usually used for timber. Figure 12 shows a negative link between short trees and quality of shade for coffee because such trees were unable to provide shade for the coffee plants and led to a decrease in air circulation on plantations; there is not a positive link between tall trees and quality of shade for coffee because this was species dependent – a tall tree would have to have other attributes to be considered positive for coffee shading.

Leaf size
Big leaves were always considered good for combating soil erosion because of the area of ground they could cover and protect, but the impact on water sources was species dependent. Most species with big leaves were positively related to water source protection, the exception was coco (*Cocos nucifera*) which was negative in its impact and was classed as a ‘caliente’ species.

Leaf colour
Although leaf colour in itself was not said to impact on shade quality of coffee, it was associated with particular positive and negative tree species. It was much easier to observe than explain in words the types of leaf colour, but on the whole, ‘fresh’ looking leaves were a brighter green and more succulent looking than ‘caliente’ leaves. Leaf colour was a factor of associative identification, so farmers could point out a tree with leaves that had a ‘fresh’ look and know its associated attributes and, therefore, the impacts it was likely to have on its environment.

Rooting depth
Shallow roots were associated with keeping the soil together and avoidance of erosion, so this was always a positive impact that trees with shallow roots could have; on the other hand, deep roots could be beneficial but this was not always the case – there were good *and* bad deep roots according to farmers, depending on the trees species and how nutrient hungry there were.

4.2.1 Discussion of Table 3
Farmers classified trees into two main groups: ‘fresh’ and ‘caliente’ trees (Table 3). These local classification systems were developed mainly with relation to tree attributes like leaf texture and size, root texture and depth, canopy height and growth rate (Figure 12). Tree attributes in terms of management qualities were also mentioned by farmers, such as the ease of pruning and whether tree species were regarded as native or exotic to the local environment. Coffee growers usually called trees ‘exotic’ if they had been relatively recently introduced, rather than species that had been introduced many years ago such as orange, coffee or bananas. A full table of the tree species mentioned by farmers and their attributes can be found in Appendix 3.

Farmers in the research area were not found to divide tree impacts on soil further than ‘good’, ‘bad’ or ‘medium’, but, from looking at Table 3, it becomes clear that classifications were strongly linked; for example, ‘fresh’ trees were associated with soil and water protection. On the other hand, ‘caliente’ trees were strongly related to low protection of water and bad impacts on soil.

In a few cases, ‘caliente’ and ‘fresh’ tree species were classed as having ‘medium’ effects on soil and water. For instance, guano (*Ochroma pyramidale*) was classed as a ‘caliente tree’ but some farmers perceived it as a ‘medium’ tree for protecting water sources and providing ‘medium’ quality of shade for coffee. Furthermore, vaina de casio (*Leucaena magnifica*) was a ‘fresh tree’ but was only considered a ‘medium’ tree for both protecting water sources and shade quality for coffee. Other ‘fresh’ tree exceptions included guaba cuajinicuil (*Inga jinicuil*) and guaba cuajilote (*Inga punctata*) which were regarded as having ‘medium’ value for both shade quality for coffee and impact on soil in comparison to other *Inga* species. Consistently, however, there were not any ‘caliente’ trees considered as having any ‘good’ impacts or ‘fresh’ trees as having any ‘bad’ impacts on soil and water.

The classification of trees into the ‘fresh’ and ‘caliente’ categories was shaped by the shade quality they were observed to offer coffee. Trees were stated as either ‘not used’ for shading coffee or providing ‘bad’, ‘medium’ or ‘good’ shade. For instance, trees that were ‘not used’ for shading coffee were those species that were never or very rarely found within coffee plantations; farmers would either know of these species from using them on other parts of the farm or because they was present in the nearby forests. A tree that provided ‘bad shade for coffee’ would be one that farmers understood to have a competitive interaction with coffee but was found within coffee plantations because of other reasons that overrode the competition aspect (usually income related). Trees that provided ‘good shade for coffee’ were deemed the most appropriate species to intercrop with coffee and were usually the most abundant within coffee plantations.

Table 3. This table represents all the trees present in the knowledge base, excluding those mentioned in the notes. It shows the local classification system for trees in the research area and the species that fit into these different categories. 'Good' means that the tree was said to decrease soil erosion, maintain soil moisture and protect water sources. The opposite is true for 'bad'. Trees with 'medium' value for shade type and shade quality were neither strongly positive nor negative in their effects upon coffee productivity, and trees with 'medium' value for their impact on soil and water were good but not *as* good in comparison to the trees classed as 'good' (see Appendix 3 for a full table of tree attributes alongside these classifications).

Trees		**Local functional classifications**			
Scientific name	**Local name**	Type of shade (fresh or caliente)	Quality of shade for coffee	Shading impact on soil	Impact on water protection
Erythrina berteroana	*Helequeme*	Fresh	Good	Good	Good
Erythrina fusca	*Bucaro*	Fresh	Good	Good	Good
Musa spp.	*Banano*	Fresh	Medium	Good	Medium
Cordia alliodora	*Laurel*	Caliente	Bad	Bad	Bad
Inga vera	*Guabilla*	Fresh	Good	Good	Good
Gliricidia sepium	*Madero negro*	Fresh	Good	Good	Medium
Cecropia obstusifolia	*Guarumo*	Fresh	Medium	Good	Medium
Pinus oocarpa	*Pino*	Caliente	Medium	Bad	Bad
Eucalyptus deglupta	*Eucalipto*	Caliente	Bad	Bad	Bad
Cedrela odorata	*Cedro real*	Medium	Medium	Medium	Medium
Persea americana	*Aguacate*	Medium	Medium	Medium	Good
Mangifera indica	*Mango*	Fresh	Bad	Good	Good
Theobroma cacao	*Cacao*	Medium	Bad	Good	Medium
Citrus aurontifolia	*Limón*	Medium	Bad	Bad	Medium
Bactris gasipaes	*Pejibaye*	Caliente	Bad	Bad	Bad
Psidium guajava	*Guayabo*	Caliente	Bad	Bad	Bad
Ricinus communis	*Higuerilla*	Fresh	Good	Good	Medium

Cocos nucifera	*Coco*	Caliente	Bad	Bad	Bad
Tabebuia rosea	*Roble*	Caliente	Bad	Bad	Medium
Citrus sinensis	*Naranja*	Medium	Bad	Bad	Medium
Ficus spp.	*Matapalo*	Medium	Medium	Medium	Good
Ficus spp.	*Chilamate*	Fresh	Medium	Good	Good
Trichilia hirta	*Alamo*	Medium	Not used	Medium	Medium
Prosopis juliflora	*Acacia*	Medium	Bad	Medium	Medium
Undefined	*Acacia africana*	Caliente	Medium	Bad	Bad
Andira inermis	*Almendro*	Caliente	Not used	Medium	Medium
Cinnamomum verum	*Canela*	Medium	Medium	Medium	Medium
Swietenia macrophylla	*Caoba*	Medium	Medium	Medium	Medium
Undefined	*Capulin*	Caliente	Bad	Medium	Medium
Carapa guianensis	*Cedro macho o cocula*	Medium	Good	Medium	Medium
Ceiba pentandra	*Ceibo*	Fresh	Medium	Good	Good
Lonchocarpus minimiflorus	*Chaperno*	Medium	Bad	Medium	Good
Tamarindus indica	*Comenegro o tamarindo*	Medium	Medium	Medium	Medium
Undefined	*Coralito*	Medium	Bad	Medium	Good
Platymiscium pinnatum	*Coyote*	Medium	Medium	Medium	Medium
Solanum bansii	*Cuernavaco*	Fresh	Good	Good	Medium
Pseudosamanea guachapele	*Gavilán*	Medium	Medium	Medium	Bad
Acosmium panamense	*Granadillo*	Caliente	Medium	Bad	Bad

Inga sapintoides	*Guaba blanca*	Fresh	Good	Good	Good
Inga oerstediana	*Guaba colorada*	Fresh	Good	Good	Good
Inga nobilis	*Guaba negra*	Fresh	Good	Good	Good
Inga jinicuil	*Guaba cuajinicuil*	Fresh	Medium	Medium	Good
Inga punctata	*Guaba cuajilote*	Fresh	Medium	Medium	Good
Andira inermis	*Guacamaya blanca*	Medium	Bad	Bad	Bad
Undefined	*Guacamaya roja*	Medium	Bad	Medium	Bad
Guazuma ulmifolia	*Guacimo*	Medium	Medium	Medium	Medium
Enterolobium cyclocarpum	*Guanacaste*	Medium	Not used	Good	Good
Ochroma pyramidale	*Guano*	Caliente	Medium	Medium	Medium
Hymenaea courbaril	*Guapinol*	Caliente	Bad	Medium	Bad
Terminalia oblonga	*Guayabo liso*	Caliente	Not used	Bad	Bad
Bursera simaruba	*Jiñocuao o Indio pelado*	Medium	Not used	Good	Medium
Spondias purpurea	*Jocote ciruelo*	Medium	Not used	Medium	Medium
Cordia gerascanthus	*Laurel de la India*	Medium	Not used	Medium	Good
Leucaena salvadorensis	*Leucaena*	Fresh	Not used	Good	Medium
Liquidambar styraciflua	*Liquidambar*	Caliente	Bad	Medium	Medium
Calycophyllum candidissimum	*Madroño*	Medium	Medium	Medium	Medium

Delonix regia	*Malinche*	Medium	Not used	Medium	Medium
Citrus reticulata	*Mandarina*	Medium	Bad	Medium	Medium
Rhizophora mangle	*Mangle*	Fresh	Not used	Good	Good
Melicoccus bijugatus	*Mamón chino*	Medium	Medium	Medium	Good
Moringa oleifera	*Marango*	Medium	Medium	Medium	Good
Cordia collococca	*Muñeco*	Fresh	Good	Good	Good
Azadirachta indica	*Nim*	Medium	Not used	Bad	Medium
Juglans olanchana	*Nogal*	Caliente	Medium	Bad	Bad
Brosimum alicastrum	*Ojoche*	Medium	Bad	Medium	Good
Bombacopsis quinata	*Pochote*	Medium	Medium	Bad	Medium
Croton draco	*Sangriento o sangredado*	Caliente	Bad	Medium	Medium
Vernonia patens	*Tatascame*	Medium	Not used	Medium	Medium
Leucaena magnifica	*Vaina de casio*	Fresh	Medium	Good	Medium

Notes: demajaue (undefined), pera de agua (undefined), chilca (undefined), mamon nacional (undefined but thought by a technician to be a variety of mammon chino (*Melicoccus bijugatus*)) and mango rosa (undefined but thought to be a variety of mango (*Mangifera indica*)) were all trees that could not be verified by more than one source and were not seen by the researcher himself; they remain in the knowledge base but were excluded from this table.

Just 11 of the 69 tree species described by farmers were considered as providing good shade for coffee (Figure 13), but many of the other trees were still abundant within coffee plantations even though they lacked this attribute. This was because their other products outweighed the shade factor; fruit trees were some of the species that remained despite providing 'medium' or 'bad' shade for coffee (e.g., avocado or *Citrus* spp. like lemon or orange). Timber use, need for live fences, medicinal value, and rate of natural regeneration strongly affected the abundance of trees within plantations. There were particular tree species that were never grown within coffee plantations because their interaction with coffee plants was deemed too unproductive, but farmers also had detailed knowledge of these trees and, depending on their utility, would keep them within the farm but not intercropped with coffee.

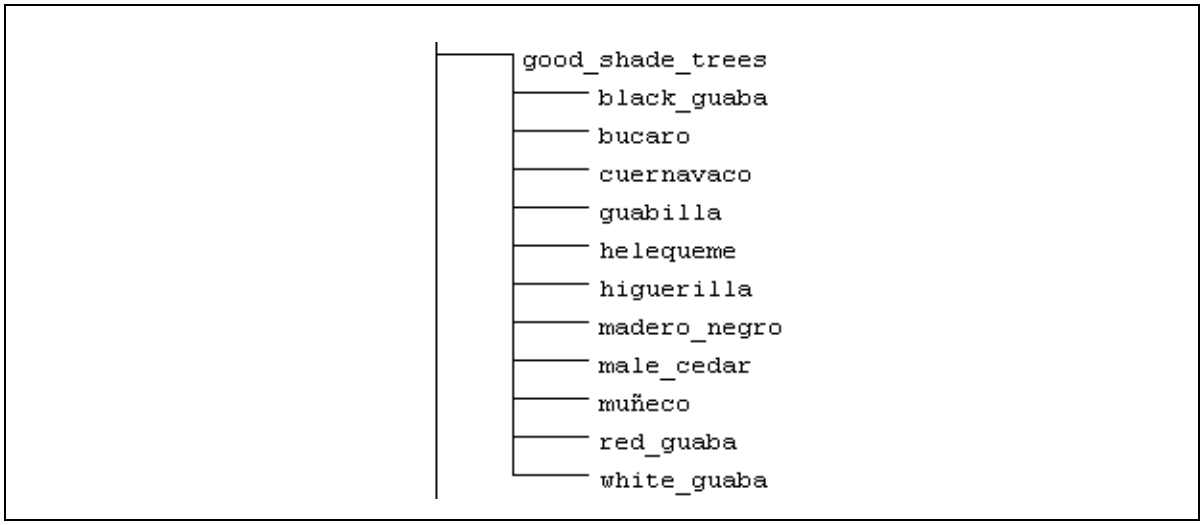

Figure 13. Showing the list of trees classified as 'good shade trees' within the object hierarchy of 'shade trees'.

Inga spp. was considered by farmers to have the most desirable attributes for growing within coffee plantations and this meant that it had the highest abundance, out of all shade trees, across the coffee farming landscape. In Table 3, four species of *Inga* (*I. vera, I. sapintoides, I. nobilis* and *I. oerstediana*) are given as interacting in a 'good' way with soil, water and coffee, while two are 'good' for soil, 'medium' for protecting water and 'medium' for their impacts on coffee (*I. punctata* and *I. jinicuil*). The differences between these species were minimal but observable by farmers, one of the differences being the leaf texture of *I. punctata* and *I. jinicuil*; they were said to have less 'fresh' leaves than the other four *Inga* species mentioned above, meaning they were comparatively harder in texture.

All *Inga* spp. were 'fresh' trees, and were kept on farms for various reasons, including *soil improvement* and *soil conservation*; they were also stated to require less strenuous management than other shade trees. *Inga vera* was the dominant species because of its easy reproduction and management. There were other reasons for keeping particular tree species on a farm over others and one of these was for firewood, vital for everyday household tasks. This was a major reason why farmers preferred *Inga* instead of *Erythrina* species, even though *Erythrina* was said to be very similar in its interactions with coffee and providing water and soil benefits.

Another abundant species in coffee plantations was banana, classed as a 'fresh' tree and grown primarily for its fruit. Although banana was considered as 'fresh' with 'good' impacts on soil, and 'medium' shade for coffee, farmers interviewed explicitly mentioned that intercropping bananas with coffee had an adverse effect on coffee growth, despite banana leaves and stem contributing towards increased soil organic matter. This was explained as happening because of too high a level of nutrient competition between banana and coffee plants. The following unitary statement has eight sources appended to it and shows that growing a high amount of banana can lead to a decrease in soil fertility; this was because the nutrient requirement of banana was said to be more than its contribution of organic matter (Figure 14). Banana fruits from the research area were well valued on the national market and gave reason for farmers to keep them within the coffee plantations, particularly because banana selling was possible throughout the year (unlike coffee which was seasonal).

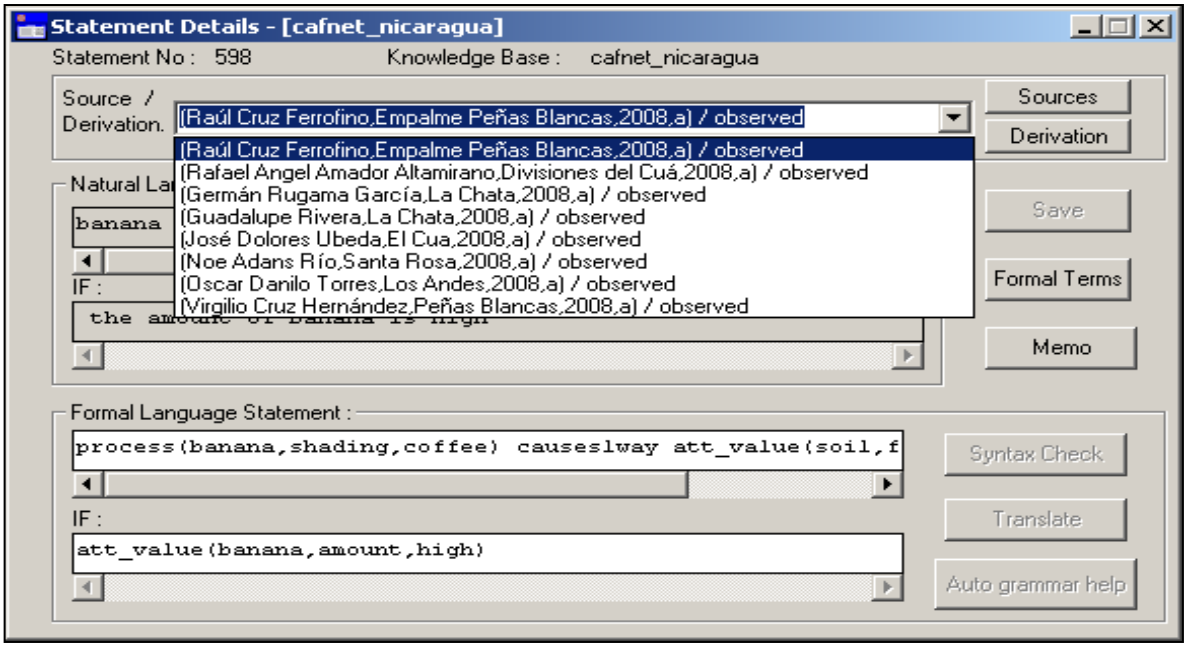

Figure 14. Kb Statement No. 598 showing the impact of growing a high amount of bananas with coffee, with eight sources appended to it.

4.2.2 Summary

Trees were classified largely according to the main extremes of 'fresh' and 'caliente' and this helps to show the ideal shade trees to be used within coffee plantations in comparison to the less ideal. But, the reason for growing particular species with coffee was not usually just for the shading properties they possessed; if they were useful in other ways then they would often still be kept in plantations. Some trees from each of the categories 'fresh', 'caliente' and 'medium' were not used; this was either because they did not provide products of livelihood value or coffee plantations were not the right environment for them and they were grown elsewhere.

Tools

Useful AKT tools:

- Cafnet tool 'hierarchic_objects_usage'. Can be used to see all the object hierarchies that particular trees appear in.

- Knowledge evaluation tool 'object_hierarchies' (found in AKT5/Tools/System Tools/Knowledge Evaluation). Can be used to see the number of statements attached to each object hierarchy. It is vital to note that the number of statements does not indicate the level of utility that those statements might represent; there might be few statements of great utility in comparison to many statements of less useful knowledge.

4.3 Coffee plantation composition, soil fertility, climatic regulation and water provision

The land area used for coffee cultivation was continually increasing around Macizo Peñas Blancas, but although this was beneficial for farmer livelihoods, the increase in coffee meant a reduction in forest areas. Farmers were aware of the forest decline and recognised the negative effects this was having upon the environment; coffee on its own could not provide the necessary conditions for a fully functioning ecosystem in comparison to the long evolved natural forest areas. Because of the management practices required to maintain good yields, coffee plants were not the ideal nesting place for creatures and it was only if they were intercropped with favourable plant and tree species that there was scope for birds and mammals to nest, visit and feed in plantations.

Many farmers, both small and large, were trying to maintain forested areas within their farms for many reasons: to protect groundwater levels, to avoid soil erosion on sloped land, and/or because a portion of land was unsuitable for growing coffee and other crops. Socio-economic factors were influencing the existence of trees and forested areas within farms, but there were also individual preferences amongst farmers that shaped whether they decided to grow more trees or not. Some farmers kept forest areas on their farms because the management requirement was less than coffee, or simply because they enjoyed having forested areas within the landscape.

Forests were generally considered the best (and sometimes the only) way to provide all the ecosystem services described above. This explains why some farmers (especially those with enough land) were keeping zones without crops, that acted as small 'reserves', within their farms. In addition, they could obtain some services from these zones in the form of firewood, timber, medicine or just the pleasure of keeping biodiversity refuges.

How coffee plantations were managed really shaped the impact they could have upon the environment, both positively and negatively. Depending on whether coffee was grown on its own or with other plants and trees; the level of pruning and weeding; the amount of chemical applications throughout the year and when these took place were all factors that had an effect on soil condition and water protection, as well as micro-climatic implications. These factors were influenced by farm size, farmer preference and financial constraints.

4.3.1 Coffee plantation composition

Across the small and medium sized farms, coffee was grown most often with *Musa* spp. (Plate 5), *Inga* spp. and a few other tree species. In the larger farms, there was less diversity and only *Inga* spp. was intercropped with coffee. All the plantations had weeds growing at the ground level, and these would be treated with herbicides and/or cut manually with machetes. Grasses were referred to as 'bad weeds', while some herbs were said to be 'good weeds' (Figure 15); in the smaller farms, farmers tended to cut the 'bad weeds' with machetes and leave the 'good weeds'. On the bigger farms, workers were employed to cut

the weeds and this led to far less discrimination between the 'good' and the 'bad' weeds because it would take longer and, thus, be more costly for farmers. It was also found that particular trees on plantations led to less problematic weeds because of the leaf fall and shade management (Kb Statements No. 45, 149, 151 and 332), but this was more likely to occur on small and medium farms because of the higher shade tree density than the large farms. The cafnet_nicaragua Kb shows that the farmers who practiced 'low conventional' methods of coffee farming gave the most information about good *and* bad weeds, while the farmers who practiced 'high conventional' methods and had more than 10 manzanas of coffee plantations did not mention 'good' weeds at all.

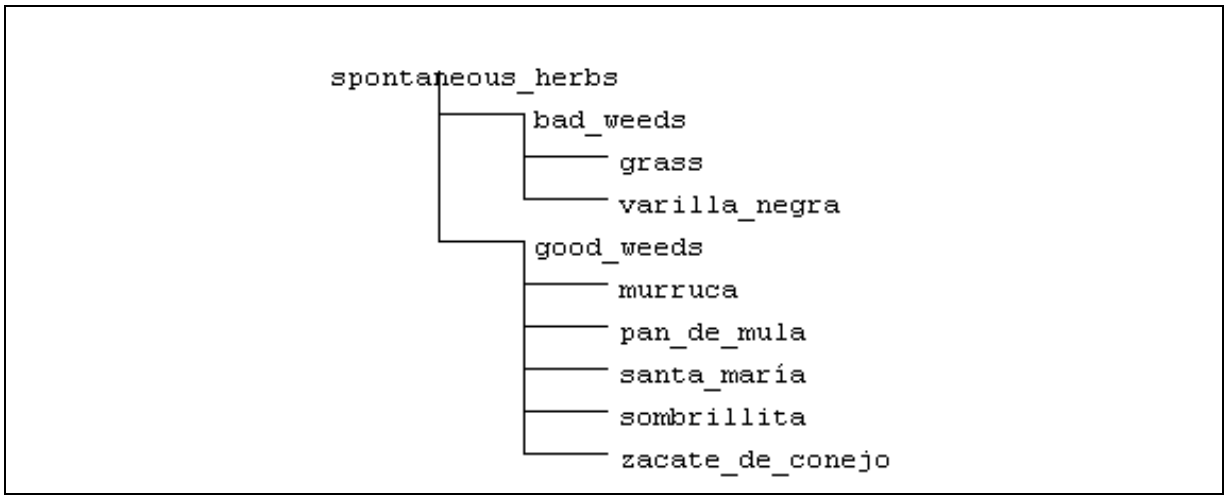

Figure 15. Shows the 'spontaneous_herbs' object hierarchy with its subobjects of 'bad_weeds' and 'good_weeds' and the species that fall under these categories.

There were a few different varieties of *Coffea arabica* present on farms which were grown separately because they were originally planted at different times so a space would have already been filled by one variety. There was not said to be any other reason for not mixing varieties, but technicians said that it made it easier in terms of management to grow them in different plots (e.g., times would vary for fertiliser applications, pruning, harvesting). The main varieties were catimor and caturra (Figure 16), with small amounts of other varieties present on some farms. The 'variety_old' shown in Figure 16 refers to the coffee varieties used over 50 years ago, that farmers referred to when talking about the past. The old varieties were said to have been more shade tolerant than those grown since; the coffee plants grown in recent years were chosen more for their larger berries and higher yields.

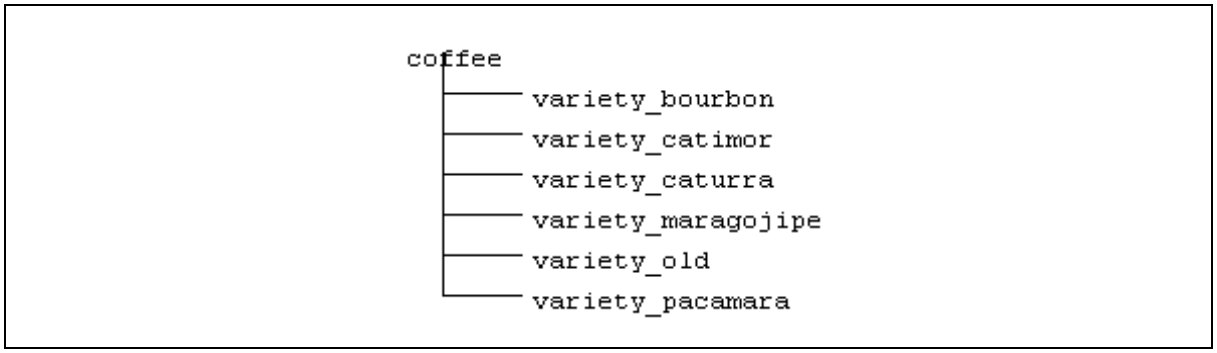

Figure 16. Shows the 'coffee' object hierarchy with its coffee variety subobjects.

Plate 5. Intercropping of banana with young coffee plants in La Chata community. Photograph taken by Carlos Cerdán, June 2008.

Complex multi-strata coffee agroforests were not established because farmers understood that an increase in the level of shade was not economically viable because of the impact on coffee productivity. The rate of trees shading coffee was seen to affect its growth in ways that were related to overall coffee productivity (Figure 17). One factor impacting on coffee growth was the amount of sunlight received by the plant. Farmers said that shade was important to protect coffee plant but only when the sun shining rate was very high. Coffee farmers observed that too much shade leads to a low amount of sunlight reaching the coffee plants which leads to a reduction in number of leaves and, consequently, the energy required for flowering and fruit formation is not enough. Shade was further related to increased levels of diseases, mainly fungal diseases, with some farmers associating the presence of coffee borers with a high level of shade.

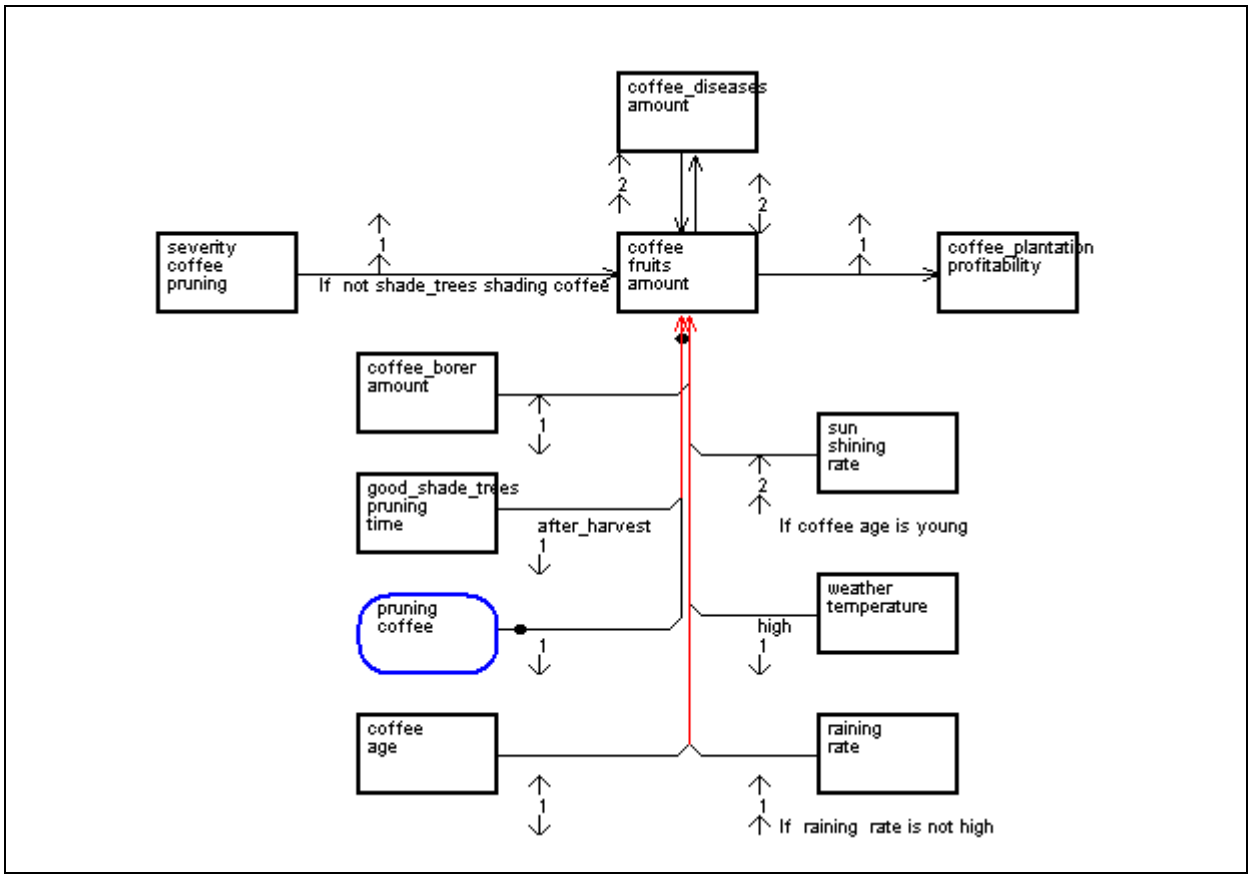

Figure 17. AKT causal diagram showing major factors that have an effect on coffee productivity. Nodes represent human actions (boxes with rounded corners) or attribute and values of objects, processes or actions (boxes with straight edges). Arrows connecting nodes denote the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second arrow on a link refers to an increase (↑) or decrease (↓) in the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case ↑A causing ↓B also implies ↓A causing ↑B, or one-way (1), which indicates that this reversibility does not apply. Words instead of small arrows denote a value of the node other than increase or decrease (e.g. when weather temperature is **high**, there is a decrease in coffee fruits amount). Conditions are shown where applicable next to the causal relationship arrows (e.g, **if** raining rate is not high). A black dot on a causal arrow indicates a negation of the node it is coming from or going to (e.g. **not** pruning coffee causes the amount of coffee fruits to decrease).

4.3.2 Soil fertility

The amount of leaves produced and released by trees was highly related to the importance attributed to them as providers of nutrient cycling and soil organic matter. The trees present in the 'good soil trees' object hierarchy' (Figure 18) were those that were said to produce high levels of organic matter and/or were associated with nitrogen fixation. Out of these 21 'good soil' species, however, only nine were regarded as providing 'good quality shade for coffee' (see Table 3), showing that just because a tree is beneficial for soil, it might not necessarily be an appropriate species to intercrop with coffee.

Inga spp. (guaba) was widely considered the best option for soil nutrient status, due to the amount of leaves produced and their texture; the leaves fell all year round and were valued for providing a thick litter layer. Leaf texture was considered by farmers as the most valuable characteristic of leaves because of the effect this could have on degradability and

soil organic matter formation (as can be seen from Figure 12, leaf texture was said to affect both shade quality and soil fertility).

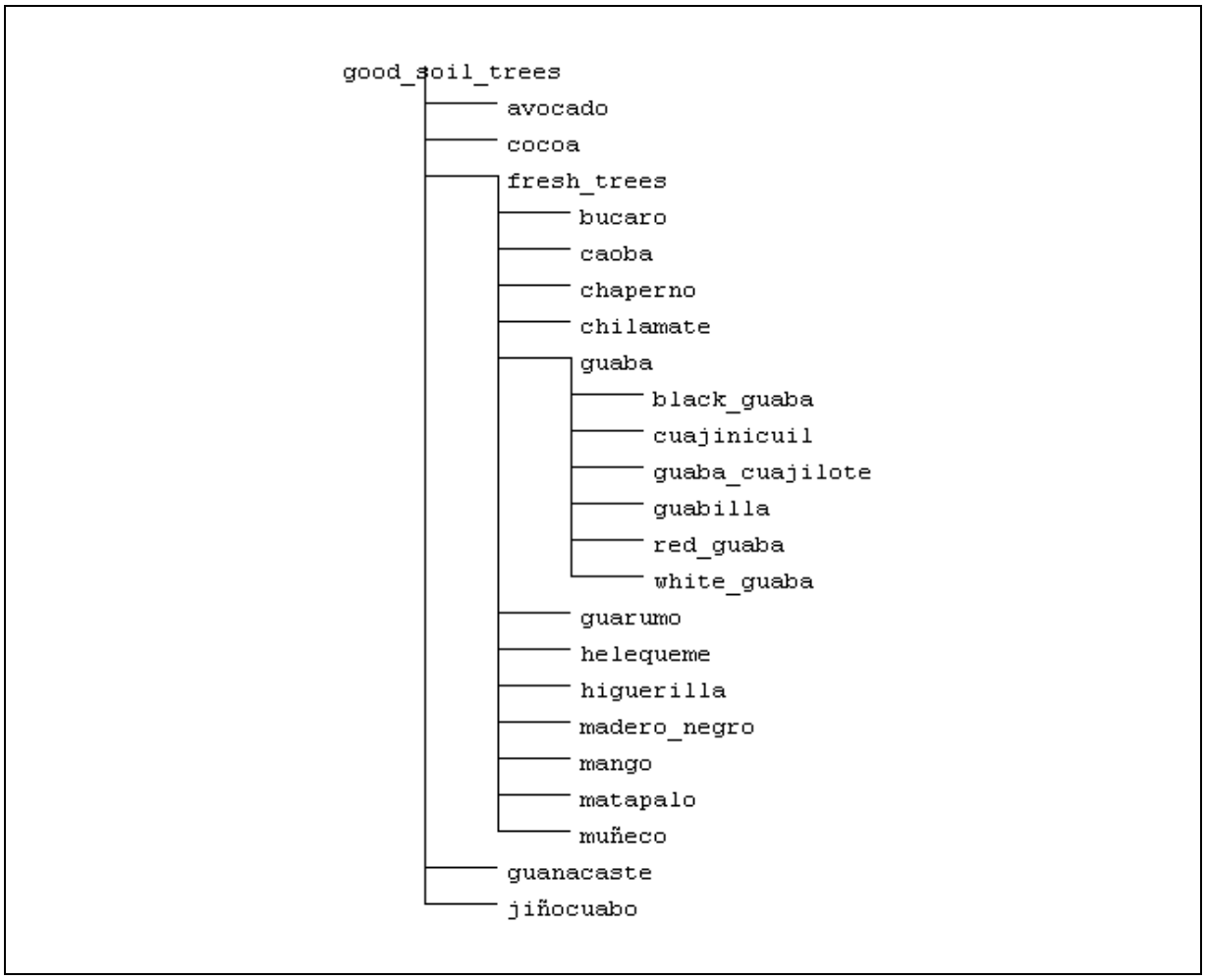

Figure 18. Shows the 'good_soil_trees' object hierarchy with its subobjects.

Tree leaf litter and root systems, herbicide applications and weeds were considered major factors influencing soil erosion and could be managed in ways that could either increase or reduce erosion and, therefore, soil fertility. It was more often that farmers appreciated the function of trees in conserving soil across areas with steep slopes rather than gently sloped and flat land. They also considered weed roots as helping against soil erosion and this was the main reason why organic and some conventional farmers disagreed with herbicide application. The statements about herbicide use in the knowledge base all indicate that it can lead to an increase in soil erosion and decrease in soil fertility, because it kills weeds ('good' and 'bad') and seedlings of native tree species (*observed* on farms), as well soil microorganisms (*heard* at training sessions). For two farmers in Los Andes Community, it proved cheaper to plant good shade trees to control weeds than apply herbicides (Kb Statement No. 269); one of these farmers was certified organic and the other was considered low conventional in his methods.

4.3.3 Climatic regulation and water provision

At a coffee plantation scale, farmers did not plant trees in a particular way to exploit their ability to draw water up from deep in the ground or help rain water infiltrate the soil. However, they were very careful in the case of trees around natural springs and streams and often left the trees alone that naturally grew in those locations. Farmers had knowledge of the specific species that were useful for protecting water sources (represented in Table 4) and stated the important role that tree cover can play in water storage and purification. Such water 'services' were seen as best supplied by forest areas rather than cropped land, but trees on farms were still associated with providing benefits in terms of regulating moisture in the soil and air, something frequently mentioned by farmers. Coffee agroforestry systems were said to enhance water provisioning services if there were high numbers of shade trees interspersed with the coffee, and such systems compared favourably against cattle farming; however, it was clear that farmers regarded coffee agroforests as less than favourable in this aspect when compared with forest areas. Replacement of forest with *any* crop was said to impact negatively on water provisioning and regulation.

The majority of farmers in the research area managed the trees within their coffee plantations in a similar way, the exception being two large plantations that were located centrally inside the reserve and were not visited for interviews. Most farmers kept a high number of shade trees, with different degrees of pruning being carried out depending on individual opinion about shade level requirement during the dry and rainy seasons and dis/advantages of intensive coffee management. Despite the perception that intercropping trees with coffee was not as effective as keeping forest areas for regulating the local climate, some farmers were increasing the amount of shade trees because of microclimatic benefits that were important for successful coffee plant development. Farmers observed that trees helped, in particular, during the dry season when sunlight could be very intense and had the potential to heat and dry up the soil. Tree canopies filtered sunlight and helped to retain soil moisture within coffee plantations which meant that pruning was generally carried out far less during the dry season, but *when* and *how* farmers would manage their shade trees was further influenced by farm location and topography factors. There was generally overlap between when shade trees and coffee plants were pruned so that coffee plants could benefit from higher sunlight levels.

The climate was understood to have a high impact on coffee productivity and changes in season length were considered to be locally felt conditions of global climate change. Coffee farmers said that trees were vital in reducing impacts of global warming (called locally 'recalentamiento'), but that temperature regulation on this scale only works when trees are part of forests rather than dispersed amongst crops. There was no further detail attached to these statements as farmers could not explain why this was the case. Climatic change leading to more extreme weather conditions was given as the primary reason for experimenting with coffee varieties. Farmers were trying to assess the implications of seasonal change on growing conditions for coffee, and by experimenting they were equipping themselves with knowledge that could potentially prove useful in the long term.

It was not only trees that could contribute to water provisioning services; as mentioned earlier, a few farmers appreciated the role of ground cover plants that were classed as 'good weeds'. It was said that these weeds, such as pan de mula, murruca, santa maria, sombrillita and zacate de conejo (Figure 15), were considered beneficial for coffee plantations because

they were keeping soil moisture at a sufficient level for coffee plants and also because their roots were binding together the soil, thus, avoiding erosion.

4.3.4 Summary

Within coffee plantations, it was not just the tree species that was important for maintaining soil moisture, pruning at different levels for different times of the year according to where the farm was situated was also important. A good coffee yield could be obtained when shade level was low in dry season because this was the growth stage at which coffee plants were increasing their number of leaves; whereas, when the rainy season starts, shade was observed to protect ripening fruits. It was said that shade levels should never be excessive because this can lead to decreased coffee yields and increased disease incidence.

Farmers showed a good understanding of which trees and plants were useful in terms of decreasing soil erosion, maintaining soil moisture and deeper groundwater, but explanations were often lacking further detail. Although physical attributes of trees were well linked with environmental impacts, the actual processes were not so clearly understood or able to be verbally expressed. Moreover, the reasons given for keeping particular trees on coffee plantations were not the associated beneficial environmental impacts; a tree would often have to prove itself useful in additional ways to be kept there, for example providing a food source. Where there was an important water source in the landscape, however, farmers were careful and did not tend to disturb the natural species composition around these areas in case it led to a diminishing water supply. Water supply was not usually a problem in coffee plantations around Macizo Peñas Blancas Reserve, but suitable water for human consumption was a problem in the urban areas in the lower ranges around the reserve (particularly during the dry season); this was partly because of a lack of effective water storage facilities. Farmers were aware of this and it was likely to be the reason for them thinking that water should be protected in the forest and in the coffee farms.

Tools

Useful AKT5 tools:

- Boolean Search tool (found under KB/ Boolean Search). Can be used to search statements that are attached to particular formal terms, sources and user values.
- Topics (found under KB/ Topics). Can be used to pull up statements that have been grouped together as topics, such as ‘Soil erosion’, ‘Soil fertility’ or ‘Water infiltration’.

5. References

CAFNET (unpub. 2007) "Annex 1: Description of the Action". *European Commission Grant Application Form: Programme on Environment in Developing Countries*.

CEPAL (Economic Commission for Latin America and the Caribbean of the United Nations Organization) (2002) *Centroamérica: El impacto de la caída de los precios del café. Series: Estudios y Perspectivas*, No. 9, pp. 61.

Dixon, H.J., Doores, J. W., Joshi ,L. and Sinclair, F.L. (2001) *Agroecological Knowledge Toolkit for Windows: Methodological guidelines, computer software and manual for AKT*5. School of Agricultural and Forest Sciences, University of Wales, Bangor.

ICAFE (Coffee Costa Rican Institute) (2005) *Informe sobre la actividad cafetalera de Costa Rica*, pp. 85.

Lashermes, P. and Anthony, F. (2007) "Coffee". In: Kole, C. (ed.) *Genome Mapping and Molecular Breeding in Plants: Technical Crops*. Berlin, Heidelberg, Springer, pp. 109-118.

MARENA (unpub. 2003) "Plan de manejo de la Reserva de la Biosfera Bosawas".

Me´ndez, V. E., Gliessman, S. R. and Gilbert, G.S. (2007) "Tree biodiversity in farmer cooperatives of a shade coffee landscape in western El Salvador", *Agriculture, Ecosystems and Environment*, 119, pp. 145–159.

Moss, C., Frost, F., Obiri-Darko,B., Jatango, J.A., Dixon, H. and Sinclair, F.L.,(2001) *Local knowledge and livelihoods:tools for soils research and dissemination in Ghana.* School of Agricultural and Forest Sciences, University of Wales, Bangor.

Osorio, N. (2002) *The Global Coffee Crisis: A Threat to Sustainable Development*. ICO, London, UK.

Pagella, T. F.,Chalathon, C., Preechapanya, P., Moss, C. and Sinclair, F.L. (2002) *Local knowledge about watershed functions in Northern Thailand: A guide to using the Agroecological Knowledge Toolkit (AKT).* School of Agricultural and Forest Sciences, University of Wales, Bangor.

Sinclair F.L. and Joshi, L. (2000) "Taking local knowledge about trees seriously". In Lawrence, A. (Ed) *Forestry, forest users and research: new ways of learning.* ETFRN Series No 1, European Tropical Forest Research Network, Vienna, pp 45-61.

Sinclair, F. L. and Walker, D. H. (1998) "Acquiring qualitative knowledge about complex agroecosystems. Part 1: Representation as natural language". *Agricultural systems* 56, pp. 341-363.

Sinclair, F.L. and Walker, D.H. (1999) "A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension". In: L.E. Buck, J.P. Lassoie and E.C.M.

Waliszewski, W.S., Mabote, R. and Sinclair, F.L. (2003) *Local ecological knowledge about rangeland agroecology in the highlands of Lesotho: A guide to using the Agroecological knowledge Toolkit (AKT).* School of Agricultural and Forest Sciences, University of Wales, Bangor.

Walker, D.H. and Sinclair, F. L. (1998) "Acquiring qualitative knowledge about complex agroecosystems. Part 2: Formal representation". *Agricultural systems* 56, pp. 365-386.

Appendix 1: Tools for analysing the knowledge

The '**Tools**' in AKT5 perform automated reasoning. '**System tools**' come with the AKT5 software, whereas, '**Other User Tools**' are developed with a specific knowledge base or collection of knowledge bases in mind (in this case CAFNET knowledge bases). The tools enable the user to analyse and compare knowledge in a much more powerful manner than would otherwise be possible using simple '**Boolean search**' operations.

Tools are used primarily for two distinct functions - 1) to facilitate the development of knowledge bases and 2) knowledge base exploration (especially when there is more than one knowledge base to be interrogated at the same time).

Table 4. Useful tools for CAFNET knowledge bases.

Name of Tool	Description	Tool Location
knowledge_base_report	Produces a report that summarises the main Kb content	System tools/ Knowledge Evaluation
formal_terms_table	Tabulated output that shows all formal terms and their presence across all open Kbs	System tools/ Comparative Analysis
interactions_amongst_components	Tabulated output that shows the number of interactions between object hierarchies or singular objects within the Kb statements	Other User Tools/ cafnet_tool file
phenology analysis	Comparative analysis tool that pulls up all common topics across Kbs and presents the topic search terms (e.g. flowering, pollinating) with their associated objects, attributes and values in a tabulated output	Other User Tools/ cafnet_tool file
get_components(Kb,Objects,Synonyms)	Pulls up all selected objects and their synonyms	Other User Tools/ cafnet_tool file
get_objects(Kb,Objects)	Pulls up all selected objects with their subobjects and/or superobjects depending on user	Other User Tools/ cafnet_tool file

	specified search criteria	
hierarchic_objects_usage	Compares objects across object hierarchies and shows which hierarchies they appear in	Other User Tools/ cafnet_tool file
hierarchical_actions_and_processes	Shows the actions and processes associated with the objects within a selected object hierarchy	Other User Tools/ cafnet_tool file

Appendix 2: Glossary

Table 5. Key terminology and concepts using AKT5

AKT5 term	Description
Action	A type of formal term used to refer to a human activity, usually for the purpose of managing crops or livestock, e.g. 'weeding' or 'planting'
AKT5	Agroecological Knowledge Toolkit: a methodology and software for creating knowledge bases
Attribute	A type of formal term used to describe an object, process or action. Attributes are generally measurable e.g. height, colour, frequency, rate, gradient, temperature
Boolean search	A keyword search mechanism for retrieving statements containing particular key words. Any combination of words may be used in conjunction with 'AND' and 'OR'
Causal statement	A statement about the causal relationships between two objects, processes or actions
Comparison	A type of formal term used in comparison statements
Comparison statement	A type of statement that compares the properties of two objects
Conditions	The conditions that need to be in place for a specific statement to be true
Control structures	When working with tools: program segments within AKT5 which control when and upon what knowledge primitives are used
Data	A set of observations which may be quantitative or qualitative
Derivation	The origin of the information given by a source (e.g. observed, hearsay, unknown)
Diagram	A way of graphically representing causal and link statements
Formal language	The restricted syntax (grammar) by which knowledge is entered into AKT5
Formal term	Terms (words) that constitue a formal language statement that do not belong to the reserved AKT5 grammar
Knowledge	The outcome, independent of the interpreter, of the interpretation of data or information
Knowledge base (Kb)	An articulated and defined set of knowledge stored on a computer which can be accessed and processed systematically
Link	a) A type of formal term used in a link statement b) On a diagram – the connection between two nodes represented by an arrow
Link statement	A type of statement used to represent knowledge that cannot be represented by any other type of statement
Local knowledge	Knowledge based on a locally derived understanding, formed by experience and observation
Memo	A facility within AKT5 which provides the Kb creator with space to add any additional explanatory information about a knowledge base, formal term, statement, bit map, diagram, topic.
Natural language statement	A statement which has been automatically translated by AKT5 from the 'formal language' to a 'natural language' computer stylised translation

Navigate	A command used when working with diagrams that adds to a diagram all the causal nodes immediately associated with a user selected node
Node	Causal and link statements can be represented on a diagram by two nodes connected by a link. A 'node' is the diagrammatic representation of one half of a causal or link statement and appears as a rectangular or circular box. There are four types of node: i) objects, ii) processes, iii) actions and iv) attributes of either objects, processes or actions
Object	A type of formal term used to refer to a material or conceptual thing e.g. pests, shade trees or coffee plantation
Object hierarchy	A way of organising knowledge about specific objects under more generic terms e.g.*avocado trees* and *bananas* are all types of fruit tree
Primitives	Small program segments within AKT5 employed for running a tool
Process	A type of formal term used to refer to a change or a flux in the natural world e.g. decomposition, erosion
Prolog (WinProlog)	An artificial intelligence programming language used for developing AKT5 software
Source	The origin of the information contained within a statement. There are two types of sources: interview sources and reference sources
Subobject (of an object)	An object that appears below another object in an object hierarchy e.g. '*Grevillea robusta*' would be a subobject of 'trees'
Superobject (of an object)	An object that appears above another object in an object hierarchy. e.g., 'trees' would be a superobject of '*Grevillea robusta*'
Synonym	A word with the same meaning as a formal term; usually used to denote a local or scientific name for a specified species, and as a method for switching between English and the language of the particular research site. There can be any number of synonyms.
System tools	Tools stored within AKT5 which can be used to interrogate and evaluate the content within knowledge base(s)
Tool	A small computer program supplied with AKT5 that serves to interrogate and reason with the content of the knowledge base(s)
Topic	A collection of statements organised around a particular topic e.g. 'bio-indicators of clean water' or 'miang pests'
Topic hierarchy	A collection of topics organised under a broader 'umbrella' topic area
User defined tools	Tools created by the knowledge base user that are stored separately to the main AKT5 program file with an .mcr extension
Value	A type of formal term that is always attached to an attribute and describes that attribute e.g. 5kg, yellow, high, increase
WinAKT	The old name for AKT5: Agroforestry Knowledge Toolkit for Windows

Appendix 3: Full table of tree species, their attributes and classification by coffee farmers in Macizo Peñas Blancas

Table 6. Shows the local classification system for trees in the research area and the species that were said to fit into these different categories. Under 'Tree attributes', the local classifications were made by comparing the tree species found in the research area with one another. Under 'Local functional classifications', 'good' means that the tree was said to decrease soil erosion, maintain soil moisture and protect water sources. The opposite is true for 'bad'. Trees with 'medium' value for shade type and shade quality were neither strongly positive nor negative in their effects upon coffee productivity, and trees with 'medium' value for their impact on soil and water were good but not *as* good in comparison to the trees classed as 'good'.

Trees		**Tree attributes**									**Local functional classifications**			
Scientific name	Local name	Height	Growth rate	Prune easiness	Leaf size	Crown	Leaf texture	Canopy	Origin	Root system	Type of shade (fresh or caliente)	Quality of shade for coffee	Shading impact on soil	Impact on water protection
Erythrina berteroana	*Helequeme*	High	Fast	Medium	Big	Open	Very soft	Deciduous	Exotic	Soft and plentiful	Fresh	Good	Good	Good
Erythrina fusca	*Bucaro*	High	Fast	Easy	Big	Open	Very soft	Evergreen	Exotic	Soft and plentiful	Fresh	Good	Good	Good
Musa spp.	*Banano*	Low	Fast	Easy	Big	Open	Soft	Evergreen	*Native	Soft	Fresh	Medium	Good	Medium
Cordia alliodora	*Laurel*	High	Fast	Not pruned	Small	Open	Hard	Deciduous	Native	Hard	Caliente	Bad	Bad	Bad
Inga spp.	*Guabilla*	Medium	Fast	Easy	Medium	Closed	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Good
Gliricidia sepium	*Madero negro*	Low	Fast	Medium	Medium	Closed	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Medium
Cecropia obstusifolia	*Guarumo*	High	Fast	Not pruned	Too big	Open	Soft	Evergreen	Native	Soft	Fresh	Medium	Good	Medium
Pinus oocarpa	*Pino*	High	Fast	Not pruned	Small	Open	Hard	Evergreen	Native	Hard	Caliente	Medium	Bad	Bad
Eucalyptus deglupta	*Eucalipto*	High	Medium	Not pruned	Medium	Open	Hard	Deciduous	Exotic	Hard	Caliente	Bad	Bad	Bad
Cedrela odorata	*Cedro real*	High	Fast	Not pruned	Medium	Open	Medium	Deciduous	Native	Medium	Medium	Medium	Medium	Medium
Persea americana	*Aguacate*	Medium	Fast	Medium	Medium	Open	Medium	Evergreen	Native	Medium	Medium	Medium	Medium	Good
Mangifera indica	*Mango*	Medium	Fast	Medium	Medium	Closed	Medium	Evergreen	*Native	Medium	Fresh	Bad	Good	Good
Theobroma cacao	*Cacao*	Low	Fast	Easy	Big	Closed	Medium	Evergreen	Native	Medium	Medium	Bad	Good	Medium
Citrus aurontifolia	*Limón*	Low	Fast	Medium	Medium	Closed	Medium	Evergreen	*Native	Hard	Medium	Bad	Bad	Medium
Bactris gasipaes	*Pejibaye*	High	Medium	Not pruned	Medium	Open	Hard	Evergreen	Native	Hard	Caliente	Bad	Bad	Bad
Psidium guajava	*Guayabo*	Low	Medium	Medium	Small	Closed	Hard	Evergreen	Native	Hard	Caliente	Bad	Bad	Bad
Ricinus communis	*Higuerilla*	Low	Fast	Not pruned	Big	Open	Soft	Evergreen	Native	Soft	Fresh	Good	Good	Medium

Cocos nucifera	*Coco*	High	Medium	Not pruned	Big	Open	Hard	Evergreen	Native	Hard	Caliente	Bad	Bad	Bad
Tabebuia rosea	*Roble*	High	Medium	Not pruned	Medium	Closed	Medium	Deciduous	Native	Hard	Caliente	Bad	Bad	Medium
Citrus sinensis	*Naranja*	Low	Fast	Medium	Medium	Closed	Medium	Evergreen	*Native	Hard	Medium	Bad	Bad	Medium
Ficus spp.	*Matapalo*	High	Fast	Difficult	Medium	Closed	Medium	Evergreen	Native	Hard	Medium	Medium	Medium	Good
Ficus spp.	*Chilamate*	Medium	Fast	Not pruned	Medium	Closed	Medium	Evergreen	Native	Soft	Fresh	Medium	Good	Good
Trichilia hirta	*Alamo*	Medium	Medium	Not pruned	Medium	Closed	Medium	Evergreen	Native	Medium	Medium	Not used	Medium	Medium
Prosopis juliflora	*Acacia*	Low	Fast	Not pruned	Medium	Closed	Medium	Evergreen	Native	Hard	Medium	Bad	Medium	Medium
Undefined	*Acacia africana*	Medium	Medium	Not pruned	Medium	Closed	Hard	Evergreen	Native	Hard	Caliente	Medium	Bad	Bad
Andira inermis	*Almendro*	Low	Slow	Not pruned	Big	Open	Medium	Deciduous	Native	Medium	Caliente	Not used	Medium	Medium
Cinnamomum verum	*Canela*	Medium	Medium	Not pruned	Medium	Closed	Medium	Evergreen	Exotic	Medium	Medium	Medium	Medium	Medium
Swietenia macrophylla	*Caoba*	High	Slow	Not pruned	Medium	Open	Medium	Deciduous	Native	Medium	Medium	Medium	Medium	Medium
Undefined	*Capulin*	Medium	Medium	Not pruned	Medium	Closed	Hard	Evergreen	Native	Hard	Caliente	Bad	Medium	Medium
Carapa guianensis	*Cedro macho o cocula*	High	Medium	Easy	Big	Open	Medium	Evergreen	Native	Soft	Medium	Good	Medium	Medium
Ceiba pentandra	*Ceibo*	High	Slow	Not pruned	Small	Closed	Medium	Evergreen	Native	Soft	Fresh	Medium	Good	Good
Lonchocarpus minimiflorus	*Chaperno*	High	Fast	Not pruned	Big	Open	Medium	Evergreen	Native	Soft	Medium	Bad	Medium	Good
Tamarindus indica	*Comenegro o tamarindo*	Medium	Medium	Not pruned	Small	Closed	Medium	Evergreen	Exotic	Soft	Medium	Medium	Medium	Medium
Undefined	*Coralito*	Medium	Medium	Not pruned	Medium	Closed	Soft	Deciduous	Native	Soft and plentiful	Medium	Bad	Medium	Good
Platymiscium pinnatum	*Coyote*	Medium	Slow	Not pruned	Small	Open	Soft	Deciduous	Native	Soft	Medium	Medium	Medium	Medium
Solanum bansii	*Cuernavaco*	Medium	Fast	Easy	Medium	Open	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Medium
Pseudosamanea guachapele	*Gavilán*	High	Medium	Not pruned	Medium	Open	Soft	Deciduous	Native	Soft and plentiful	Medium	Medium	Medium	Bad
Acosmium panamense	*Granadillo*	High	Slow	Not pruned	Medium	Open	Hard	Deciduous	Native	Hard	Caliente	Medium	Bad	Bad
Inga sapintoides	*Guaba blanca*	Medium	Medium	Easy	Medium	Open	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Good
Inga oerstediana	*Guaba colorada*	Medium	Medium	Easy	Big	Open	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Good
Inga nobilis	*Guaba negra*	Medium	Medium	Easy	Medium	Open	Soft	Evergreen	Native	Soft and plentiful	Fresh	Good	Good	Good
Inga jinicuil	*Guaba cuajinicuil*	Medium	Medium	Easy	Medium	Open	Medium	Evergreen	Native	Soft and plentiful	Fresh	Medium	Medium	Good

Inga punctata	*Guaba cuajilote*	Medium	Medium	Easy	Medium	Open	Medium	Evergreen	Native	Soft and plentiful	Fresh	Medium	Medium	Good
Andira inermis	*Guacamaya blanca*	Medium	Slow	Not pruned	Medium	Open	Hard	Deciduous	Native	Hard	Medium	Bad	Bad	Bad
Undefined	*Guacamaya roja*	Medium	Slow	Not pruned	Medium	Open	Hard	Deciduous	Native	Medium	Medium	Bad	Medium	Bad
Guazuma ulmifolia	*Guacimo*	Low	Fast	Not pruned	Small	Open	Soft	Deciduous	Native	Medium	Medium	Medium	Medium	Medium
Enterolobium cyclocarpum	*Guanacaste*	Medium	Fast	Not pruned	Medium	Closed	Soft	Deciduous	Native	Soft	Medium	Not used	Good	Good
Ochroma pyramidale	*Guano*	High	Fast	Not pruned	Big	Open	Medium	Evergreen	Native	Hard	Caliente	Medium	Medium	Medium
Hymenaea courbaril	*Guapinol*	Medium	Slow	Not pruned	Small	Closed	Hard	Evergreen	Native	Deep	Caliente	Bad	Medium	Bad
Terminalia oblonga	*Guayabo liso*	High	Slow	Not pruned	Small	Open	Hard	Deciduous	Native	Hard	Caliente	Not used	Bad	Bad
Bursera simaruba	*Jiñocuao o Indio pelado*	Medium	Fast	Easy	Small	Open	Soft	Deciduous	Native	Medium	Medium	Not used	Good	Medium
Spondias purpurea	*Jocote ciruelo*	Low	Medium	Easy	Big	Closed	Medium	Deciduous	Native	Medium	Medium	Not used	Medium	Medium
Cordia gerascanthus	*Laurel de la India*	High	Medium	Not pruned	Medium	Closed	Medium	Deciduous	Native	Deep	Medium	Not used	Medium	Good
Leucaena salvadorensis	*Leucaena*	Low	Fast	Medium	Small	Closed	Soft	Evergreen	Native	Soft	Fresh	Not used	Good	Medium
Liquidambar styraciflua	*Liquidambar*	High	Fast	Not pruned	Big	Open	Soft	Deciduous	Native	Deep	Caliente	Bad	Medium	Medium
Calycophyllum candidissimum	*Madroño*	High	Slow	Not pruned	Medium	Closed	Soft	Evergreen	Native	Medium	Medium	Medium	Medium	Medium
Delonix regia	*Malinche*	Medium	Fast	Difficult	Medium	Open	Medium	Deciduous	Exotic	Medium	Medium	Not used	Medium	Medium
Citrus reticulata	*Mandarina*	Low	Fast	Medium	Small	Closed	Medium	Evergreen	*Native	Medium	Medium	Bad	Medium	Medium
Rhizophora mangle	*Mangle*	Medium	Medium	Not pruned	Medium	Open	Medium	Evergreen	Native	Soft	Fresh	Not used	Good	Good
Melicoccus bijugatus	*Mamón chino*	High	Slow	Not pruned	Medium	Closed	Medium	Evergreen	Exotic	Medium	Medium	Medium	Medium	Good
Moringa oleifera	*Marango*	Medium	Fast	Not pruned	Small	Open	Soft	Evergreen	Exotic	Deep	Medium	Medium	Medium	Good
Cordia collococca	*Muñeco*	Medium	Medium	Not pruned	Big	Closed	Hard	Evergreen	Native	Medium	Fresh	Good	Good	Good
Azadirachta indica	*Nim*	Low	Not adapted	Easy	Small	Closed	Medium	Evergreen	Exotic	soft	Medium	Not used	Bad	Medium
Juglans olanchana	*Nogal*	High	Fast	Not pruned	Small	Open	Hard	Deciduous	Native	Superficial and hard	Caliente	Medium	Bad	Bad

Brosimum alicastrum	*Ojoche*	High	Slow	Difficult	Small	Open	Medium	Evergreen	Native	Superficial and hard	Medium	Bad	Medium	Good
Bombacopsis quinata	*Pochote*	Medium	Medium	Not pruned	Small	Open	Medium	Deciduous	Native	Deep	Medium	Medium	Bad	Medium
Croton draco	*Sangriento o sangredado*	Medium	Medium	Not pruned	Medium	Open	Hard	Deciduous	Native	Hard	Caliente	Bad	Medium	Medium
Vernonia patens	*Tatascame*	Low	Fast	Not pruned	Medium	Open	Soft	Deciduous	Native	Medium	Medium	Not used	Medium	Medium
Leucaena magnifica	*Vaina de casio*	Low	Fast	Easy	Small	Open	Soft	Evergreen	Native	Soft and plentiful	Fresh	Medium	Good	Medium

*Native: many of the trees considered native by farmers were classified scientifically as exotic; this difference was because farmers had grown used to them due to introduction of the species a long time ago.